Egypt. Survey department
The topography and geology of the Fayum Province of Egypt
by H. J. L. Beadnell

NORTH SIDE OF THE BIRKET EL QURUN, LOOKING WEST.

SURVEY DEPARTMENT,
EGYPT.

THE TOPOGRAPHY AND GEOLOGY

OF THE

FAYUM PROVINCE

OF EGYPT

BY

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INTRODUCTION.

The geological survey of the desert surrounding the Fayûm was commenced in October 1898. At that time the area, although so near to Cairo, was little known; the Rohlfs Expedition maps marked the region as "unexplored," and in fact with the exception of a publication by Schweinfurth, who had traversed the region from north to south, *via* Qasr el Sagha and Gar el Gehannem to Rayan, there was little information obtainable. The area being of considerable size (12,000 sq. kilom.) and almost unexplored, both geologically and topographically, the primary object was to construct as rapidly as possible a general map of the depression, at the same time laying down in broad outline the chief geological formations and trusting to future opportunity to examine in more detail places of special interest.

Commencing work at Sêla, on the eastern side of the depression, the survey was carried northwards along the east side of the cultivated lands and thence through the northern desert, up to the summit of the depression. After mapping westwards as far as the isolated hill-mass of Gar el Gehannem the work was temporarily suspended until, in the spring, the narrow defile of Wadi Muêla, and the Wadi Rayan, forming the southern part of the Fayûm depression, were provisionally examined.

In January 1901, samples of soil and water from the cultivated lands were collected as an experimental soil-survey, and the results have been published.[1]

During the winter's work of 1902-03 a traverse was carried from Gar el Gehannem in a south-west direction through a hitherto unexplored part of the depression. On reaching a point midway between Cairo and the oasis of Baharia a connection was made eastwards to Wadi Rayan. In the winter of 1903-04 further exploration was carried out in the neighbourhood of Gar el Gehannem.

It will be convenient here to briefly relate the history of the discovery of the remarkable series of new and extinct animal forms, the recovery of which from the Fayûm deposits has created such widespread interest in the zoological world. When Schweinfurth crossed the region in 1879 he obtained fossil bones, which were examined and determined by Dames to be the remains of cetacea of the genus *Zeuglodon*, from certain beds of the escarpment west of Qasr el Sagha; these, it is believed, were the earliest vertebrate remains obtained from the Fayûm. During the early part of the survey of the district, remains of fish and crocodiles were frequently found in one of the beds of the Middle Eocene, probably on the same horizon as that from which Schweinfurth had collected. Fragments of bone were also commonly met with on a much higher horizon (*i.e.*, near the base of the Fluvio-marine series) but nothing of particular interest was obtained, as no detailed search could

[1] A. Lucas, *A preliminary investigation of the Soil and Water of the Fayum Province;* Survey Dep., P.W.M. Cairo, 1902.

be made at that time. In April 1901, during the survey of the western end of the Birket el Qurûn, some of the localities found to be bone-bearing in 1898 were re-visited in company with Dr. C.W. Andrews, who was in Egypt at the time and had accompanied the survey in order to obtain specimens of jackals, hares, etc., for the British Museum, in connection with the forthcoming work on Egyptian mammals. In one of these Dr. Andrews picked up several vertebrae which turned out to belong to a new species of *Pterosphenus*.

Further north, when descending the Middle Eocene escarpments at a place not previously examined, we crossed the outcrop of the bone-beds at a point where a considerable number of mammalian and reptilian bones lay exposed on the surface, many in an excellent state of preservation. The importance of the find was evident, and a short examination of the material on the spot enabled Dr. Andrews to pronounce the discovery to be of the highest importance from a palaeontological point of view.

Some three weeks' work in the immediate neighbourhood resulted in a very good collection of vertebrates from the Middle Eocene beds, including several new genera afterwards described[1] under the names of *Eosiren*, *Barytherium*, *Mœritherium*, *Gigantophis*, etc. Moreover, a fossil tooth brought in by one of the camelmen from a point several kilometres to the north led to a careful examination of the lower beds of the overlying Upper Eocene formation, which resulted in obtaining well-preserved remains belonging to a new genus, since described as *Palaeomastodon*. All the material so far obtained was taken home to be worked up and determined at the British Museum and a preliminary description was published by Dr. Andrews in the Geological Magazine.

In the winter of 1901-02 the survey of the Fayûm was resumed with the special intention of following up the highest beds, those in which *Palaeomastodon* had been found. Continued search westwards eventually led to the discovery of the remains of a large and remarkable horned ungulate (*Arsinoitherium*), a preliminary notice[2] of which was published in the spring of 1902. Shortly after, the remains of several new smaller mammals and reptiles (*Phiomia*, *Saghatherium*), including the shell of a large land tortoise (*Testudo Ammon*), were obtained[3]. Further work in the winters of 1902-03-04 led to a great deal more material being obtained[4], mostly of course belonging to the same species, but including some new genera *Geniohyus*, *Megalohyrax*, *Pterodon*.

The amount of palaeontological material is now so large that the Egyptian Government has arranged with the Trustees of the British Museum for the publication of the whole in a monograph to be issued by the Trustees. The present report, therefore, deals only with the geology and topography of the district.

[1] ANDREWS, *Extinct Vertebrates from Egypt*. Parts I and II. Geol. Mag. N. S. Dec. IV, Vol. VIII, Sept. and Oct. 1901, pp. 400-409 and 436-444.

[2] BEADNELL, *A Preliminary Note on Arsinoitherium Zitteli, Beadn.* Survey Dept. P. W. M., Cairo, 1902. See also *A New Egyptian Mammal (Arsinoitherium) from the Fayûm.* Geol. Mag. N. S. Dec. IV, Vol. X. Dec. 1903, pp. 529-532.

[3] ANDREWS and BEADNELL, *A Preliminary Note on Some New Mammals from the Upper Eocene of Egypt.* Survey Dept. P. W. M., Cairo, 1902.

[4] ANDREWS, *Notes on an Expedition to the Fayûm, Egypt, with Description of some New Mammals.* Geol. Mag. N. S. Dec. IV, Vol. X. Aug. 1903, pp. 337-343. Also *Further Notes on the Mammals of the Eocene of Egypt* (Parts I, II, III). Geol. Mag. N. S. Dec. V., Vol. I. March, April, May 1904.

BAHR YUSUF AT LAHUN BEFORE ENTERING THE FAYUM.

PART I.

TOPOGRAPHY AND STRUCTURAL GEOLOGY.

THE Fayûm, a large circular depression in the Libyan Desert, is situated immediately west of that part of the Nile Valley lying between Kafr el Ayat and Feshn (Plate XVII.)

The depression, which has an area, roughly speaking, of 12,000 square kilometres, is primarily divisible into three distinct parts—cultivated land, lake, and desert.

SECTION I.—CULTIVATED LAND.

The cultivated land has an area of about 1,800 square kilometres and, with the exception of the lake and part of the Wadi Rayan, occupies the lowest part of the depression. Cultivation is necessarily strictly limited to the area covered with alluvial soil. The latter, for the most part identical in origin and composition with the river-alluvium of the Nile Valley, covers a leaf-shaped tract between the bounding desert on the east side and the lake (the Birket el Qurûn) on the north-west. The easterly and central part of the cultivated area forms a more or less level table-land, from which the ground slopes gently away, especially on the north side, where the slope is towards the lake and very marked. The cultivated land of the Fayûm is directly connected with that of the Nile Valley by a narrow strip of low ground, a natural passage through the desert separating the Nile Valley and the depression of the Fayûm. Through this gap runs the natural canal known as the Bahr Yusef, which is practically the sole source of water in the Fayûm and irrigates the entire district.

The canal leaves the Nile Valley at Lahûn (Plate II), and follows a somewhat serpentine course through the desert for about 5 kilometres, irrigating a narrow strip of land on either side, which at Hawara rapidly broadens out into the wide cultivated area of the Fayûm. Once within the latter, the Bahr Yusef gives off numerous subsidiary canals which traverse the country in all directions, constantly splitting up into smaller branches until the water-supply is divided throughout the whole area. With the exception of the self-contained basin of Gharaq, on the south side of the Fayûm, the entire district drains into the Birket el Qurûn, which occupies the lowest part of the depression, to the north of the cultivation. The basin of Gharaq is irrigated by the Bahr el Gharaq, a canal which takes off from the Bahr Yusef soon after the latter enters the Fayûm [1].

[1] For fuller details of the cultivated lands, water-supply, etc., of the Fayum, the reader is referred to the excellent description by Sir Hanbury Brown in his work *The Fayum and Lake Moeris*, London, 1892.

The cultivated land of the Fayûm is traversed by two main ravines, cut down in many places to the Eocene limestone below the alluvium (Plates III and V.) At the present time these ravines carry canals for irrigating the lower parts of the district, and also act largely as drains to the higher lands. They were probably initiated by the escape of water through breaches in the Bahr Yusef during flood time, and have since been deepened to their present dimensions.

In addition to the main central cultivated area, the soil of which, as mentioned above, is essentially identical with that of the Nile Valley, large tracts of the surrounding country, more especially on the north, north-west, and west sides, are also covered with alluvial deposits. These latter, which include sands, sandy clays, and clays of a quite distinct type, represent the slowly formed accumulations of the quieter and more remote parts of the ancient Lake Moeris (and the earlier prehistoric lake). The material was mostly derived from the Eocene strata which formed the shores of the lake, augmented no doubt by a certain amount of very fine sediment drifted from the Bahr Yusef, and by sand blown in by wind.

It is noticeable that the thickest and most sandy deposits occur near the borders of the lake site; when close under the Eocene cliffs, as along the north side above the Birket el Qurûn, the deposits closely resemble those of the latter. The finer more calcareous beds occur further out and the true marls were accumulated only at some distance from the shores of the lake.

When in Ptolemaic times the lake became reduced to a fraction of its former size, large areas covered by these lacustrine clays were exposed and some portions were brought under cultivation. Subsequently, however, all these outlying districts were abandoned and became absorbed by the surrounding desert, until in modern times the cultivation was restricted to the central portion of the old lake bed, a portion almost identical with the area over which true "Nile Mud" had been deposited.

The construction during recent years of extensive irrigation works in the Nile Valley has made it possible to largely augment the water-supply of the Bahr Yusef to the Fayûm. High level canals are being cut in various parts of the district and already large areas of desert covered by these lacustrine deposits have been brought under cultivation, notably to the north of Tamia and in the neighbourhood of Qasr Qurûn. The approximate area covered with lacustrine deposits can be seen on the map and with a sufficiency of water probably the greater part of this area could be utilized, though the exact value of the soil compared with Nile deposit remains to be determined.

Section II.—THE BIRKET EL QURUN.

The lowest part of the depression, lying immediately to the north-west of the cultivation, is occupied by a sheet of water of considerable size, known as the Birket el Qurûn.[1]

[1] "The Lake of the Horns," so called from the narrow horn-like promontories which jut out into the lake on the north side. Views of the lake are shown in Plates I, IV, XVI.

The lake, which has a length of 40 kilometres, and a maximum breadth under ten, covers at the present time an area of about 225 square kilometres. Sir Hanbury Brown obtained no sounding exceeding 5 metres in crossing the lake to Dimê, but according to the fishermen the depth increases towards the south-west.

Its long axis lies nearly east and west, and while on the north it is entirely[1] bordered by desert, along a large part of the south side the cultivated land approaches its shore, although even here a large area actually bordering the lake is waste salty land as yet unfit for cultivation. As already mentioned, with the exception of the Gharaq basin, the lake receives the whole drainage from the cultivated lands.

The Birket el Qurûn is the existing remnant of the ancient prehistoric lake which covered a large part of the floor of the Fayûm depression, and which in historic times was converted into an artificially controlled sheet of water—the celebrated Moeris—by Amenemhat I and his successors in the XII Dynasty.

Lake Moeris, being used as a regulator of excessively high and low Nile floods,[2] was of the greatest importance in connection with the irrigation of the Nile Valley. In more recent times, apparently under the Persians or Ptolemies according to Flinders Petrie,[3] Lake Moeris ceased to perform its function of regulator; since that time all water, except that required for irrigation of the reclaimed land, being carefully excluded, the surface of the lake has continually and gradually sunk to its modern dimensions.[4]

Lacustrine deposits, showing approximately the actual limits of the ancient Fayûm lake, can be traced over wide areas of now barren desert; these will be more fully dealt with later. The present lake-level is still continually sinking owing to an improved system of irrigation, by which a constantly decreasing amount of waste water drains into the lake. Its average annual fall has, during the last decade, been nearly half a metre,[5] and the slope of the land being very gradual, large areas have been reclaimed during the last few years, though whether the advantages derived from this constant lowering of the lake are not more than balanced by certain drawbacks is somewhat doubtful.[6]

With the new areas now being brought under cultivation the amount of drainage water finding its way into the lake will increase and the fall be checked. At the beginning of 1904 the level was markedly higher than in the previous winter, and a difference of even half a metre alters the shore line to a considerable extent, owing to the flatness of the land by which the lake is for the most part bounded.

Although under the present desert conditions practically no material from the surrounding desert is washed into the lake, doubtless a considerable amount of fine dust and sand is carried into it by the wind, especially during the violent sandstorms which occur frequently

[1] This was the case until a year or two ago. At the present time a limited amount of freshwater finds its way to the area immediately north of the east end of the lake and small plots are cultivated by the arabs.

[2] *Herodotus*, Book II; *Strabo*, Book XVII; and *Diodorus Siculus*, Book I, Chap. LI. (See Brown op. cit. p. 19-22.)

[3] "*Hawara, Biahmu and Arsinœ,*" 1889.

[4] Brown, op. cit. p. 95. As mentioned above in some areas the cultivated land was formerly even more extensive than at present, notably near the modern villages of Roda, Tamia, etc.

[5] For details of evaporation and level-records of the lake, see Brown, op. cit. pp. 6-9, and P.W.M. annual reports.

[6] See Willcocks' *Egyptian Irrigation*, 2nd edition, London, 1899.

in the locality. The high cliffs which bound the northern shore of the lake throughout a portion of its length probably have the effect of checking the velocity of both north and south winds, thus causing a considerable amount of sand, which would otherwise be carried across, to be dropped on its surface. This material, together with the fine mud brought down by the canals on the cultivation sides, must have an appreciable effect in raising the level of the bed of the lake.

The phenomenon of the extraordinary freshness of the water of the Birket el Qurûn has been commented on by Schweinfurth, who shows that the degree of concentration of salt in a lake whose volume has been continually reduced, and to which salt has constantly been added, should be many times greater than the actual existing amount. An analysis[1] of the water at the west end of the lake (where the concentration is greatest, owing to the distance from the feeder canals) showed that the total salts amounted to only 1·34%, of which 0·92% was sodium chloride. Dr. Schweinfurth[2] concludes that the lake has a subterranean outlet, which alone would enable it to maintain its comparative freshness.[3] In this connection it is interesting to note the existence of distinct currents, which may possibly be caused by such outlets, in certain localities on the north side of the lake; and it is just possible that a careful survey of the lake itself would not only prove the existence, but show the exact position, of such underground outlets.

Most probably, however, the currents are simply local movements produced by temporary differences of level, which might conceivably be caused in such a large and comparatively shallow sheet of water, varying considerably in salinity in different localities, by wind and evaporation.

The comparative freshness of the lake and the possible presence of underground outlets are of the highest importance in their bearing directly on two of the most important questions in connection with the proposed utilization of the Wadi Rayan as a reservoir, i.e. what the leakage from such a reservoir would be and to what degree of salinity its water would attain.

Section III.—THE SURROUNDING DESERT REGION.

With the exception of the lake and the cultivated area the depression is practically entirely desert. The southern and south-western parts include the wadies Rayan and Muêla, where freshwater springs occur, surrounded by areas covered by a good deal of wild scrub. Apart from these, however, no springs occur outside the cultivated land.

The topography of the region is so intimately connected with its geological structure that an adequate description of the former is not possible without constant reference to the latter. Full geological details will, however, be reserved for later consideration.

[1] See *A Preliminary Investigation of the Soil and Water of the Fayûm Province*, by A. Lucas, Survey Department, Cairo. 1902.

[2] See Appendix II, *A Note by Dr. Schweinfurth on the Salt in the Wadi Rayan*, in Willcocks' *Egyptian Irrigation*, pp. 460-465.

[3] The word "freshness" is used comparatively, as the amount of salt is sufficient to make the water unpalatable or unfit for drinking, except near the feeder canals. It is, however, quite good enough for most culinary purposes, and camels will usually drink from it, although it is not advisable to water the latter from the lake either before or after a fatiguing desert march, as in such cases the salinity of the water may have bad effects.

Area and Limits.

The part of the Libyan Desert dealt with in this report has, excluding the cultivated land and the lake, an area of some ten thousand square kilometres. While some portions have been examined and mapped in detail, others are still very imperfectly known, especially on the south and south-west sides. The irregular cliff-line forming the southern boundary of Rayan and the adjacent wadis may be taken as our limit in this direction, beyond lying an almost unbroken limestone plateau rising gradually and continually to the south. On the north and north-west the area under description is bounded by the southern limit of the great undulating high-lying gravelly desert-plateau which stretches with little change of character to the Mediterranean. On the east side the Nile Valley forms a convenient though not altogether natural boundary; while to the south-west our limit practically coincides with the boundary of the depression, where the floor of the latter insensibly merges into the general desert plateau.

Rocks forming the Area.

The rocks forming the area within the above limits are almost entirely of sedimentary origin, the exception being a band of hard basalt intercalated at the very top of the series and exposed only on the extreme northernmost limit of the depression. The total thickness of sediments, from the lowest beds exposed in the bottom of the Wadi Rayan to the summit of the escarpments, a day's march north of Tamia, is some 700 metres. These beds include every kind of sedimentary deposit—limestones, marls, clays, sandstones, sands and gravels, forming an ever-changing succession of rocks, varying considerably in hardness and capacity for withstanding the agents of denudation. It is not too much to say that the coming into existence of the Fayûm, with its plains, lowlying depressions, precipitous cliffs and escarpments, was largely dependent on the existence of this variable series of deposits.

Apart from the presence of sediments varying greatly in hardness and durability, the fact that the whole of the rocks have an almost constant northerly dip of two or three degrees is a point of prime importance. So small a dip may be scarcely noticeable in any one place, but over the large areas with which we have to deal its influence on the position and level of any individual bed is very marked and the topography of the region would have been essentially different if the strata had been quite horizontal.

Origin of the Fayûm.

The unique character of the Fayûm is alone sufficient to show that special causes have acted in its production. Two main causes stand out: — (1) the presence of thick bands of comparatively soft arenaceous and argillaceous strata breaking up the usually continuous hard limestone of the Middle Eocene; (2) the effect of the Nile Valley fault in lowering the whole of the western desert (north of Assiut) relatively to the eastern. The former took place as the result of changed geographical conditions on the continent to the south at the time in question, with which however we need not deal here. On a homogeneous mass of rock weathering has little power to form depressions of any magnitude, and this is the cause of the continuous unbroken plateau which stretches southwards from the Fayûm, the underlying rocks being one continuous thick mass of hard limestone. Wherever softer intercalations

are present differential weathering takes place, and all the great depressions of the Libyan desert owe their origin to the presence of soft easily denuded strata; if the great homogeneous mass of Nile Valley limestone had stretched unchanged westwards, the oases of Farafra and Baharia would never have existed. They owe their origin entirely to the presence of the underlying saddle of softer Cretaceous rocks. Similarly if changed conditions had not led to the deposition of soft beds of clay, marl, and sandstone, the western plateau would have continued unbroken northwards.

A comparison of the two sides of the Nile Valley between Cairo and Assiut shows that the tectonic movements, which largely determined the existence of the valley itself, resulted in a considerable lowering of the rocks forming the western side. This was brought about by differential movements along the north and south line or lines of fault, and by the presence of an east to west monoclinal fold which is especially well marked in the neighbourhood of Heluan. The depressions of the Fayûm would doubtless have existed irrespective of this general lowering of the western desert relative to the east, but denudation would have required an additional period of many thousands of years before the floor of the depression was low enough to allow of its actual connection with the Nile river.

As it has been maintained that the Fayûm is an area let down and enclosed by faults, it may be mentioned here that all available evidence points in an opposite direction; this question of faults will however be dealt with in detail later. The influence of the Nile Valley fault has been explained above and it must be remembered it is one affecting not the Fayûm alone but the northern part of the western desert as a whole.

For purposes of description it will be convenient to divide the whole region into three parts: first, the southern portion, including the wadis Muêla and Rayan; secondly, the central area, comprising the extensive plain forming the floor of the depression as a whole, and including the areas under cultivation and the Birket el Qurûn, as well as the desert separating the Fayûm from the Nile Valley. Thirdly, the northern portion, embracing all the rising ground between the floor and the northern rim of the region. These areas will now be taken in order.

Section IV.—WADI RAYAN AND NEIGHBOURHOOD.

This part of the Fayûm is of special interest in consequence of its possible future as a reservoir. Although the area has not yet been examined in detail by the Geological Survey it will be useful to bring together all the information that is at present available.

Colonel Western's Survey.

In 1882, as a counter-project to other irrigation schemes, Cope Whitehouse suggested[1] utilising as a reservoir the Wadi Rayan, a depression which had been referred to by Linant de Bellefonds.[2] At the request of Sir Colin Scott Moncrieff the Government deputed Colonel Western to make plans of the Wadi Rayan and surrounding country and to ascertain

[1] "Bull. of the American Geographical Society, 1882, pp. 22 and 24."
[2] *Mémoires sur les travaux publics en Egypte, Paris, 1873, pp. 53, 54.*

the capacity of the depression and its capability of being used as a reservoir. Liernur Bey under his direction prepared a contoured map, and Colonel Western's report, plans, and estimates were published.[1] Some general details of the wadi and surrounding hills are given and the detailed survey showed that the 30 metre contour line (above sea-level) enclosed an area of 706 square kilometres (170,000 feddans). The lowest points of the depression were found at 42 metres below sea-level. The sand, scrub and springs are briefly referred to and the discharge of the latter is given as equal to that of a very slow-going four inch hand pipe, the water running out at about + 20 m. and disappearing in the sand. Wadi Muêla was found to be separated from the Rayan depression by sandhills and rock at a mean level of + 50 metres, the lowest point in Muêla being at + 25 metres. A line of levels was run from Rayan through Muêla to the Nile Valley, the highest point crossed being at + 105 metres; for fifteen kilometres the level was not below + 75 metres. In order to find the most suitable passage for a canal to connect the Nile with the Wadi Rayan two lines of level were made after a reconnaissance of the hills near Sidmant el Jebel: the southern, from Ezba Menesi Ali, near the Gharaq canal, to Mazana on the Bahr Yusef, being considered the best. Along this line the highest point was only at + 44·7 metres and the average + 35 metres along four kilometres. Borings were not made here but judging from the surface excavation would be mostly in soft limestone, sand, and conglomerate. A much shorter route is from Deshasleh on the Bahr Yusef over the hills about 5 kilometres to the south of Mazana or Sidmant into the Wadi Gharaq, a distance of 30 kilometres. This route was not however levelled but is fairly straight and apparently not much higher than the Mazana passage.

The survey of the + 30 metre contour line of the Wadi Rayan proved that there were only two outlets into the Fayûm, both on the northern side: these two openings are only from 400—500 metres wide and their lowest points are not below + 25 or + 26 metres.

Later Government Publications by Scott Moncrieff and Willcocks.

In 1889 Sir C. Scott Moncrieff published[2] a further note, in which he briefly discussed the probable cost and benefits to be derived from the suggested reservoir, concluding that at least the project was one worthy of being thoroughly examined.

In 1894 the plans and designs in connection with the Wadi Rayan were published[3] and the possibility of utilizing the Wadi Rayan was examined by Sir William Willcocks, then Director General of Reservoirs, from an engineering point of view, and the questions of its probable cost and future utility were discussed. In this report it is stated that the routes proposed by Colonel Western in 1888 pass through salty marls and clays unsuitable for holding canals. Another route is suggested, which after leaving the Nile Valley crosses the high desert ridge in a straight line, passing through the so-called Wadi Liernur (Wadi Lulu of Cope Whitehouse); this depression is 12 kilometres long and has its bed some 24 metres below the general level of the desert. Plate 15 of the report shows the Wadi Rayan, the deserts between it and the Nile Valley and the cultivated land. The map was

[1] G. A. Liernur, Col. Western and Col. Sir C. C. Scott Moncrieff, K. C. M. G. *Notes on the Wadi Rayan*, Cairo, 1888.

[2] *Note on the Wadi Rayan Project*, Cairo, 1889.

[3] *Perennial Irrigation and Flood Protection in Egypt*, by W. Willcocks, M.I.C.E. Dir. Gen. of Reservoirs, with A Note by W. E. Garstin, Under Secretary of State, P.W.M., Cairo, 1894.

3

begun by Col. Western and completed by Willcocks. The lowest point of Wadi Rayan is shown as -42 metres and the depression is separated from the Fayûm by a limestone ridge generally from $+34$ to $+60$ metres, except at two places where it falls to $+26$ metres above sea level on a length of 600 metres. Within the $+27$ metre contour line the wadi has an area of 673 square kilometres and a capacity of 18,743,000,000 cubic metres. Between it and the Nile Valley lie 30 kilometres of desert, of which 11 are occupied by a marked depression discovered by Liernur Bey in 1887. At the extreme western edge of the Nile Valley (here 20 kilometres wide) runs the Bahr Yusef. Comparing the proposed Wadi Rayan reservoir and the ancient Mœris and allowing for a difference of 4·5 metres between the levels of the Nile Valley in B. C. 2,000 and to-day, Willcocks assumes that the high water mark of Lake Mœris was at $+22·5$ metres and its area 2,500 square kilometres, against 673 square kilometres of the Wadi Rayan at $+27$ metres. It is pointed out that the ancient lake had the great advantage that in those days the Bahr Yusef was an important branch of the Nile, if not the main river itself, and the reservoir was connected with the Nile by a natural ravine of great length and short breadth, across which a massive embankment was thrown and destroyed annually, the surplus water of high floods being stored for the deficiency of low floods.

The published sections along the lines of borings put down show the different strata cut through by the proposed canal. The Nile Valley, along the line of the inlet canal, consists of hard clay 6 to 10 metres thick, lying on coarse sand. Along the outlet canal sandy clays and clays alternate to a depth of 10 metres. On entering the desert sands and sandy conglomerate, with gypsum and salt, are met with below the surface, then a yellow marl with salts, and finally a plastic black clay overlying the Parisian limestone. These beds are most extensive in the narrow neck of land between the Nile Valley and the Fayûm and to some 10 kilometres to the south of it. They rise to $+70$ metres. There are some other marls inside the Wadi Rayan or in the adjacent depressions and as they have to be traversed by the canals form a serious factor, being easily dissolved in water; in consequence Willcocks chose the alignment of the inlet canal along the Bahr Belama where the extent of these beds would only be 2·5 kilometres against 9 kilometres on the alternative route marked on the plan. A narrow neck of land, some 15 kilometres in length, runs between the Fayûm and the depressions traversed by the proposed Wadi Rayan canal; this neck is the continuation of the salty marls and clays, but the limestone is near the surface and is overlain by a thin deposit of sand and pebbles, with freshwater shells on its northern slope at $+22·50$ metres; the southern slope is entirely devoid of them. Willcocks points out that it is evident the ancient Mœris rose to $+22·50$ metres but its water never penetrated into the Wadi Rayan. The report goes into details of inlet and outlet canals, discharge, necessary masonry works, cost, and compares the different reservoir schemes.

After a careful review of the whole question, the scheme, while considered perfectly feasible as far as available data went, was abandoned by Sir William Garstin[1] in favour of the less costly and more useful Nubian reservoir.

[1] The engineering details of the Wadi Rayan reservoir project have since been more fully discussed by Sir William Garstin in his "*Report on the Basin of the Upper Nile*" Cairo, (pp. 6-9 Appendix I).

EL WADI, RAVINE NEAR QASR GEBALI.

Schweinfurth's report on the probable salt-content in Wadi Rayan Reservoir.

In an appendix[1] to the above report Schweinfurth discusses the question as to how salt the water of such a reservoir would become. He points out that the exact valuation of the salt which would be contained in this reservoir when the water had risen to + 27 metres cannot be accurately determined, owing to the absence of information on certain points. The maximum quantity of salt in the desert soil is estimated at 2°/₀ and this figure is used in his calculation, which includes the amount of salt which would be brought into the reservoir, (1) from the Nile during filling and in the extra water entering to replace that lost by evaporation in the lake and canals; (2) from the ground forming the bed of the lake (far the largest item); (3) from the bed and banks of the inlet canal, both in the desert and in the Nile Valley; and (4) from infiltration. The figure obtained is 7,500 million kilogrammes, equal to 0·04 per cent, or almost one twenty-fifth per cent of salt. This amount is only equivalent to half the salt existing in many of the well waters used in the country for irrigation. As Schweinfurth is careful to point out his calculation is based on maximum and assumed data.

Willcocks' "Assouan Reservoir and Lake Moeris".

The question of the utilisation of the Wadi Rayan as a reservoir has recently been again brought to the front, notably by Sir William Willcocks in a paper[2] read before the Khedivial Geographical Society, Cairo. The author, after pointing out the value of such a lake, working in connection with the Assuan reservoir, discusses at length the position, dimensions, and functions of the ancient Lake Moeris. It is suggested that the main canal should be cut through the desert opposite Mazana and crossing the so-called wadis Liernur and Masaigega enter the Wadi Rayan at its easternmost point. These wadis would in time become covered with alluvium and be converted into valuable cultivated land. After examining the big ravines of the Fayûm, where similar beds are exposed, the author comes to the conclusion that the maintenance of canals in the saliferous marls, which form part of the desert through which the inlet canal would pass, would offer no particular difficulties.

With regard to the questions of leakage into the Fayûm and of the water of the lake eventually becoming salted, Sir William Willcocks says, "When the old Lake Moeris, or the present Fayûm, was full of water and 63 metres higher than the bottom of the Wadi Rayan and remained so for thousands of years, there was no question of the waters having become salted or having escaped into the Wadi. The Wadi was as dry as it is to-day and the great inland sea was always fresh." As to the question of leakage into Gharaq the author considers that if water found its way into that depression it would be a distinct advantage, as such water could be pumped into the Nezleh canal and utilized elsewhere; he maintains at the same time that no leakage will take place. Incidentally it is mentioned that the Wadi Rayan is separated from the Fayûm by a limestone ridge, a statement which, as will be shown later, requires modification.

Wadi Rayan not yet examined in detail by the Geological Survey of Egypt.

Until a detailed geological examination of the Wadi Rayan and neighbourhood has been carried out it will not be possible to form reliable opinions on many of the questions raised in connection with the prospective reservoir. The writer's acquaintance with the area

[1] A Note by Dr. SCHWEINFURTH on the Salt in the Wadi Rayan: an appendix to *Perennial Irrigation*, etc.

[2] *The Assuan Reservoir and Lake Moeris*, London. 1904.

is limited to a traverse in 1899 from the Nile Valley through Wadi Muêla to Rayan and thence to Gharaq, and subsequently to a stay of a few days duration in the neighbourhood of the Rayan springs, after mapping the extreme south-west of the Fayûm depression. While the accompanying maps may be taken as representing fairly accurately the bolder topography of the region, they do not replace the older contoured maps of the floor of the depression and the country between it and the Nile Valley to the east, accompanying the report on "Perennial Irrigation and Flood Protection in Egypt."

The following description of this part of the district is based on a traverse from the Nile Valley through the wadis Muêla and Rayan to Gharaq; the detailed geological sections measured and examined along the line of route will be given later.

Traverse from Nile Valley through Wadi Muêla to Rayan and Gharaq.

Between the village of El Gayat and the mouth of the Wadi Muêla (16 kilometres to the north-west) stretches a gradually rising undulating gypseous plain, superficially covered with loose sand and rounded pebbles of quartz and flint. In occasional small hills the white limestone which forms the underlying rock is visible. Near the entrance to the wadi stands a somewhat prominent conical hill composed of hard whitish fossiliferous limestone passing down into more sandy and clayey beds. The bottom of the wadi is cut out in soft green and brown clays, its surface being covered with blown sand, fragments of limestone, flints and gypsum. From the mouth of the wadi the Nile Valley cliffs run north and south in a winding irregular manner. On entering the valley several outstanding flat-topped limestone capped hills are passed on the right hand; they are in part joined to the regular bounding cliff beyond; the eastern cliff is steep and well-marked, while that on the west only outcrops here and there, buried as it is in immense accumulations of blown sand, rising in places into definite dune-ridges. Wadi Muêla has a length of some 18 kilometres and lies nearly N.W. and S.E. The central part of its floor is a sandy scrub-covered area, the lowest points lying at about + 25 metres; just at the southern edge of the scrub stands a small hill composed of hard shaly clays capped by white limestone, surrounded by a saline, superficially dry. Holes dug in this are at once filled with excessively salt water, and by evaporation of the brine in shallow troughs supplies of white fairly pure salt can be obtained. The area is known as Warshat el Melh. Banks of reeds were found growing on the north side of the saline, the surface of the latter being here composed of a soft brown sandy salty deposit, caking here and there into a hard earthy impure salt.

Warshat el Melh in Wadi Muêla.

In the lowest spots the saline frequently consists of soft wet sludge; its area is about half a square kilometre but the depth of the deposit is unknown. In the middle of the scrub-covered area to the north lies Ain Warshat el Melh, a pool of water, fairly fresh and drinkable, although ferruginous, measuring 10 by 5 metres in size and from 2 to $2\frac{1}{2}$ metres deep. The water evidently rises from a spring on the west side, round which are fifty square metres of green rushes, with some larger bushes. The ground around and above is very saliferous; between the spring and the ruins to the north the ground is sandy, with many bushes and much scrub. This ground extends two kilometres

to the west, whence it gradually passes up into great masses of drift sand; an occasional small outcrop of the top of the plateau above the sand is all that serves to locate the position of the buried cliff. On the east side the sandy ground with scrub extends about a kilometre, beyond which the plain gradually rises for another kilometre to the base of the cliff beyond, which is fairly steep and well-marked, though with an entire absence of indentations of any kind.

Close to the north end of the valley, and about 33 kilometres from El Gayat, Der el Galamûn.
lie the ruins known as Der el Galamûn bil Muêla. At the time of our visit a new square stone building was in course of erection and five or six persons were inhabiting the place. There are several small palms scattered about to the south of the monastery and an excellent running spring of clear water five hundred paces to the south-west. A new well is being sunk within the premises. To the north of the monastery the eastern cliff takes a marked trend to the west for some three kilometres, whence it resumes a northerly direction, always maintaining its character of a steep well-marked escarpment rising some 100 metres above the floor of the wadi. At the corner of the cliffs the lowest bed exposed is a white limestone; this is overlain by gypseous clays passing up into sandy beds, the latter being surmounted by the white limestone capping the escarpment.

We are here on the summit of the divide between Wadi Muêla and Wadi Rayan, Wadi Rayan.
the height of the floor being about +105 metres; to the north stretches a gradually widening bay descending to the lowest ground of the Rayan depression. Immense accumulations of sand almost block the defile and stretch away to the east, and the hitherto well-marked cliff on that side bends back and is lost to view. On the other side however, the bounding wall gradually emerges from the dunes, getting more distinct as it is followed northwards until it becomes quite clear of the sand. The first glimpse of this cliff is seen a couple of kilometres west of the pass in an outcropping headland, the next point visible being some five kilometres further west. Between these portions of the cliff are one or two outliers, surrounded by quantities of blown sand. A depression known as Wadi Korif is reported to lie to the west, and much scrub and some water is said to exist there; such a wadi is marked on Schweinfurth's map but apparently has not been examined.

Continuing in a N.N.W. direction high rather steep dunes occur on either flank, running N.N.W. and S.S.E. Between the dunes is a fairly hard undulating sand-flat affording an easy route; further on a narrow defile between the dunes leads down to the centre of the depression. The main areas occupied by blown sand are shown in the accompanying maps. The most interesting part of the depression is the bay lying to the south of the narrow well-marked promontory jutting out from the southern plateau, a huge pointer, as it were, in the direction of Gharaq; this is the Cape Rayan of Schweinfurth.

Springs in Wadi Rayan.

The bay is on three sides completely enclosed by cliffs and its floor is thickly covered by a luxurious growth of wild scrub—chiefly tamarisk and ghardag; numerous isolated palm trees occur, especially in the neighbourhood of the water which exists at several points. There are three particularly good springs,[1] the positions of which are shown on the accompanying maps. According to Colonel Western's survey the water emerges at about + 20 metres. In 1899 the water of the northern spring was found to have a temperature of 26°C. On our last visit we found an artificially constructed pool of two metres diameter and a depth of 30 centimetres ; on the west side of this were two springs, marked by the motion of the grey sand rising and falling in the vents, down which a stick could be easily pushed to a depth of two metres. The output of these springs together amounted to six litres a minute; the water was quite clear and although soft and rather ferruginous not by any means unpalatable (see analyses below). The pool lies on an open bare sandy spot and is surrounded by scattered bushes, none of which however are within fifteen metres; a sand dune lies 150 metres to the south-west, with bushes and seven or eight young palms. The southerly spring has an output of 21 litres a minute, and its water does not differ essentially from that of the northern spring. Rising at the foot of a palm tree it forms pools on either side; thence it flows a distance of 20 metres into an artificially constructed shallow basin 2 to 3 metres across, from which it runs away down the slope and disappears after five or six metres. The east spring, which is situated on the east side of the dunes bounding the mouth of the bay, consists of a small hole cut out in soft sand. The water seemed good, although analysis shows the salts content to be high; this spring does not run, but if emptied the hole soon refills. The remains of old buildings occur near the well, in the shape of loose roughly squared limestone blocks, broken pottery, and remains of old walls ; the latter are nearly level with the ground and very thickly and solidly built.

To the south of the promontory lies the so-called Little Rayan. Here there is a good deal of scrub, and water can be obtained on the lowest ground at a few metres depth, although there do not appear to be any surface springs.

Geology of Wadi Rayan in broad outline.

The geological succession of beds exposed in the cliffs of the promontory is given later. Broadly speaking it consists of two thirty-metre bands of hard limestone separated by 68 metres of softer sandy and clayey beds. The lower of the limestone bands in places forms the floor of the depression but more frequently the latter is composed of

[1] The following analyses of the chief springs in the Wadi Rayan, made by Mr. Lucas, Chemist to the Survey Department, are of interest:—

	North Spring.	South Spring.	East Spring.
Matter in Solution	398·8	350·8	811·6
Chlorine calculated as Sodium Chloride	278·4	238·2	585·5
Sulphur Trioxide calculated as Sodium Sulphate ...	62·9	53·9	126·2

The above figures are parts per 100,000 parts of water.

Although the above analyses prove the water to be of a very poor quality for drinking purposes, compared with many of the wells and springs of the oases, the water, which is quite clear, seemed good. Except for its softness and somewhat ferruginous taste, it is quite palatable, and on my last visit we used no other for five days. The south spring was found to yield 21 litres and the north 6 litres per minute. The water of the third spring does not run.

the overlying sandy or clayey beds. The depression is bounded on the north side by the same succession, and, as far as could be judged from observations made on the traverse, the bed of limestone capping the ridge, and forming the plain stretching away to the Birket el Qurûn and to Gar el Gehannem, is identical with that capping the cliffs to the south, i.e. is the uppermost of the two thick limestone bands. At the two points more particularly noticed, namely, the spurs projecting southwards into the depression, 23 kilometres west and 18 kilometres W.S.W. of Gharaq basin, the sequence seemed to be the same as in the southern cliffs, although, owing to the northerly dip, the upper bed of limestone lies at a much lower level and the basal beds are not exposed at all. In both these localities, however, some of the underlying clays were exposed, as well as on the lowest spots crossed between the most easterly spur (18 kilom. W.S.W. of Gharaq) and the extensive dunes lying immediately west of Gharaq cultivation. These dunes, though of no height, have remarkably steep sides. In crossing Gharaq to the Fayûm cultivation occasional beds of yellow sandy limestone were noticed, but their horizon was not determined. Numerous bored blocks, probably belonging to the marine Pliocene, were observed scattered about. Apparently the uppermost thirty-metre band of limestone passes continuously northwards under the cultivated lands of Gharaq and the Fayûm; in the ravines of the latter this limestone is not observed, the soft limestones exposed below the alluvial deposits almost certainly belonging to the overlying Ravine beds. The country to the east of Gharaq has not been geologically examined and the exact locality in which the thick bed of limestone dips underground and is overlain by the succeeding beds is doubtful. Further north, in the desert ridge east of Qalamsha, we have observed the Birket el Qurûn beds and a section measured at this point is given later.

As it appears to have been freely assumed that the ridge separating the Rayan depression from the cultivated lands of Gharaq and the Fayûm is formed throughout of solid limestone, it is important to point out that, on our assumption of the identity of the beds of limestone capping the cliffs to the south and the plain to the north of the Wadi Rayan, the dividing ridge would in part be formed of the underlying arenaceous and argillaceous beds.

Character of Ridge separating Wadi Rayan from Gharaq and the Fayûm.

The absence of Nile deposit and freshwater shells in the Wadi Rayan will, when confirmed after a thorough examination of the area, afford the strongest evidence that the depression was never directly flooded by Nile water. The fact that the dividing ridge is probably everywhere above the highest level attained by Lake Mœris, and by the still more ancient prehistoric lake, is almost sufficient in itself as a proof of this. It does not however follow that there was not leakage through the ridge into the Rayan basin, as such leakage might conceivably have taken place to a considerable extent without the water ever having collected in sufficient quantities to form even moderate sized pools within the depression. The bottom of the depression is for the most part covered with soft porous sandy deposits overlying the Eocene bed-rock below, and at the present time the

Question of leakage through dividing ridge.

water of the Rayan springs, though continually running, at once disappears from sight, drains down to the lowest parts of the depression and is then gradually lost by evaporation or underground leakage. In the lowest parts of the depression this water is, as already mentioned, met with on digging to a very moderate depth.

A careful examination of the flanks of the ridge separating the Fayûm and Gharaq cultivated areas from Rayan might prove if such leakage ever took place. If such was the case the seepage was probably along the line of junction of the limestone and underlying clayey or sandy beds. Even if it were proved that there never was leakage from Lake Mœris into Wadi Rayan, it would not be safe to assume that the converse would not happen, as the dip of the beds is from south to north and this fact is one to be reckoned with. Judging from the nature of the Eocene beds forming the Wadi Rayan, my opinion is that leakage on a large scale would not take place, and that owing to the northerly dip any water that escaped from the reservoir would pass indefinitely northwards and would not find its way through the overlying limestone to the surface either in Gharaq or the Fayûm cultivation. A detailed examination of the local geology would, however, be necessary to prove or disprove this. As to the question whether the Wadi Rayan as a whole would hold water, as far as is known there are no faults or other fissures of any magnitude through which the water could escape. No doubt a good deal of water would be lost before the smaller joints and passages, which exist in all rocks, were silted up. Schweinfurth supposes that the freshness of the Birket el Qurûn is due to the existence of subterranean outlets, and such might also be found to exist in the Wadi Rayan. In any case the argillaceous deposits from such a lake would very soon form a bed to all intents and purposes impermeable.

Degree of Salinity.

With regard to the extent of salinity of such a lake Dr. Schweinfurth's figures are of considerable interest and value, although based wholly on assumed data. The greater part of the salt would be derived from the rocks and soil forming the bed of the reservoir and only by extensive sample collecting and analysis can reliable figures be obtained. We believe that in the lowest parts of the basin the salt content of the ground would be found considerably in excess of the two per cent used by Schweinfurth in his calculation, although his total estimate would probably be found well within the mark.

Section V.—CENTRAL AREA OF THE REGION.

Central Plain at the Fayûm Depression.

The great central plain, forming the floor of the depression as a whole, is composed of a hard bed of limestone some thirty metres thick. This limestone, forming the uppermost member of the Rayan series, is, as already mentioned, almost certainly identical with that capping the cliffs to the south of the depression, and in all probability in the eastern extension of the plain under description underlies the whole of the cultivated lands of Gharaq and the Fayûm. The feature of the plain as a whole is its marked and constant, though low, dip to the north; so that its surface, bared by denudation of the overlying

soft limestones of the Ravine series, over a distance of some twenty kilometres, is a true dip-slope, at the base of which lies a strip of low-lying country extending from beyond Gar el Gehannem through the Birket el Qurûn to the Nile Valley ridge east of Tamia. The central and lowest portion of this low-lying area is occupied by the Birket el Qurûn, the bed of which lies fifty metres below sea level and is thus the lowest known spot in the whole of the Libyan desert. Thirty kilometres south-west of the western end of the lake, at the base of the dip-slope of the central plain and immediately under the southern scarps of the great outlying hill-mass west of Gar el Gehannem, lies another low lying basin, which receives the drainage from a considerable area of the plain to the south-west. The latter, consisting of the limestone above-mentioned, is here superficially covered by gravel, and its dark undulating surface is scored by numerous shallow winding water-courses marked by an abundant growth of scrubby vegetation ; some of the principal of these drain into the basin just mentioned and after heavy rainfall the water collects and forms a pool 600 metres in length by 100 to 150 metres wide. The base of the basin, at about 80 metres above sea level, is marked by a level deposit of silt of considerable thickness, the east end of the site being surrounded by great numbers of luxuriantly growing tamarisks. Other similar basins exist on the plain to the south, and under an isolated hill five kilometres W.S.W. several full grown acacias were noticed. On the low ground to the north-west of Gar el Gehannem, and at several points between it and the head of the Birket el Qurûn, similar silt covered areas exist, some being only from 30 to 40 metres above sea level.

In the extreme south-west of the region the limestone forming the central plain is gradually overlain by the succeeding beds, so that the ground rises imperceptibly to the level of the plateau separating the depression from that of Baharia, distant some two days march. On the eastern side, if the superficial alluvial deposits could be stripped off, the underlying surface of limestone, sloping from south to north, would not differ materially from the plain further west, except that here, at any rate north of Gharaq, the Rayan limestone is overlain by the basal beds of the Ravine series.

Section VI.—RIDGE SEPARATING THE NILE VALLEY AND THE FAYUM.

The desert ridge separating the Nile Valley from the Fayûm has, to the north of the Bahr Yusef, an average width of some ten kilometres ; further south it narrows, until due east of Gharaq the ridge is barely $2\frac{1}{2}$ kilometres wide. The highest points are situated to the east of Sersena and Qalamsha respectively.

In both these localities the Eocene rocks, consisting of clays alternating with beds of calcareous sandstone and sandy limestone (pp. 39, 40) are overlain by thick deposits of conglomerate and gravel, attaining altitudes of over 100 metres above the cultivated land below. From these summits the slope is usually very gradual on the Nile Valley side but much more rapid towards the Fayûm.

The ridge is cut down, however, to a comparatively low level in four localities ; to the

north-east of Tamia; to the east of Sêla, where the railway crosses; between Lahûn and Hawara, where the Bahr Yusef canal enters; and to the south of Qalamsha, where along the site of the proposed Wadi Rayan canal the highest point is only some 40 metres above the Gharaq basin and 27 metres above the adjoining Nile Valley cultivation.

Outline of earliest connection of Nile with Fayûm.

One of the most interesting problems connected with the Fayûm may be briefly alluded to here—When did the waters of the Nile first obtain access to the depression?

As will be shown later the Fayûm was occupied by the sea in Pliocene times, when the great gravel accumulations and gypseous deposits were formed. Later the area became dry and denudation of the land surface completed the work of erosion already begun in earlier times.

In Pleistocene times drainage down the Nile Valley appears to have become definitely established and probably the river in the lower part of its course eventually washed up against and broke down the separating barrier of gravel between the Fayûm and the Nile Valley, so that part of its waters obtained access to the depression, formed a lake on the lowest part, and gradually rose until the whole basin, up to the level of the channel connecting it with the Nile Valley, became filled. Every year thousands of tons of sediment were carried in by the floods and spread out on the floor in the shape of a fan. Probably later, as the Nile level fell, the valley and the depression again became disconnected, until the more modern river, with its gradually rising bed, again attained the requisite altitude. In early historic times the alluvial deposits had probably silted up the lake in its southern central part, and when in the XIIth dynasty the district was first taken in hand by Amenemhat I this part of it must have had the character of a huge marsh, nearly surrounded by open water, rapidly deepening towards the north.

Section VII.—THE NORTHERN DESERT REGION.

The Plateau bounding the Fayûm depression to the north.

All along the north-west and north sides the ground rises rapidly from the base of the dip-slope of the plain in a series of escarpments to the summit of the rim of the depression, averaging 340 metres above sea level. Northwards from the summit stretches a rolling pebbly desert, the prevailing character of which is a dark brown, relieved by lighter brown grey and yellow patches, and especially flecked by the light sandy slopes of the undulations. Although the latter seldom rise to any considerable height above the general level of the plain, from the top of the most modest eminence an immense view in every direction can frequently be obtained. The monotony of this desert is only relieved by the occasional belts of sand, which although extremely narrow in width, run for immense distances in almost absolutely straight lines, and in a N.N.W.—S.S.E. direction. Although none of these dunes actually reach the rim of the escarpment we may mention here the beautiful Ghart el Khanashat, an almost straight and apparently unbroken ridge of sand, extremely narrow but of great length. Near its southern extremity the width does not exceed 100 metres; the slopes on both sides are frequently as much as 30°. The commencement of

the Ghart el Khanashat was observed on a march from Wadi Natrûn to Mogara; it lay some way to the south of a line joining those two localities but could not be accurately fixed from the line of route. The belt dies out 24 kilometres from the rim of the Fayûm depression, its termination being particularly abrupt, although the height of the ridge diminishes gradually throughout the last kilometre or two. The line of the belt if continued would almost strike the western extremity of the Birket el Qurûn; near its termination the desert is almost flat, the surface being finely gravelly, with numerous groups of silicified trees; tufts of coarse grass grow in some profusion on the sandy ground at the base of the ridge on either side. A fairly well-marked road from the Birket el Qurûn to the Wadi Natrûn passes the end of the ridge and continues northwards at a distance of 200 metres from the east side of the dunes, although apparently gradually diverging eastwards.

Except to the north and north-west of Tamia, where a somewhat extensive and fairly level plain exists, the ground, as already mentioned, rises from the limits of the central plain in a series of escarpments to the summit of the rim of the depression. These cliff lines are broadly speaking three in number and represent the escarpments of the three great rock-stages which build up the northern part of the Fayûm, i.e., the Birket el Qurûn series, the Qasr el Sagha series, and the Fluvio-marine series. It would serve no useful purpose describing these different cliffs in detail; their positions and characters are apparent on the accompanying maps. The intervening plateaux are for the most part dip-slope plains formed of hard bands of rock, which resisting denudation, are left protecting the underlying strata while the softer beds above are cut back at a comparatively rapid rate.

Desert west and south-west of Gar el Gehannem.

In December 1902 and March 1903 a traverse was made through the unexplored country west and south-west of Gar el Gehannem, finally connecting up with Wadi Rayan. The highest escarpment, i.e. that of the Fluvio-marine series, dies out about 20 kilometres west of Gar el Gehannem, gradually merging into the undulating gravel-covered plain. The lower escarpments, those of the Qasr el Sagha and Birket el Qurûn series, continue to a considerable distance in a south-westerly direction, although gradually losing the characters of well-marked cliffs. In fact westwards of this the depression gradually shallows, until at a point some 50 kilometres southwest of Gar el Gehannem the floor has attained the level of the ordinary desert plateau, on which the outcrops of the beds of successive rock-stages follow one another in regular order from south to north, but without forming well-marked topographical features, as in the depression.

Hills, capped with dark hard ferruginous silicified grits and puddingstone, were met with in the extreme south-west extension of the depression; these deposits, which will be referred to more fully later, considered in conjunction with the similar beds occurring within the oasis of Baharia, and in the hills of Gar el Hamra, on the plateau immediately to the north-east of that depression, are of considerable interest and importance, especially in connection with the question of the position of the early rivers which in Eocene and later times brought down quantities of trees and animals, the remains of which are so abundant throughout the later Fayûm deposits.

Jebel el Qatrani and escarpments north of the Birket el Qurûn.

The boldest part of the region is the area lying between the Birket el Qurûn and the summit of the depression to the north. All three lines of cliff are here high and precipitous, and the uppermost escarpment, well known by the name of Jebel el Qatrani, formed of a highly coloured series of sandstones and clays and capped for a distance of many kilometres by a thick bed of hard black basalt, is of a most striking character. The eastern extremity of Jebel el Qatrani is perhaps the most conspicuous point in the whole region; here the two conical black basalt-capped cliff-outliers, known as Widan el Faras, stand side by side, and from their summits the eye commands the whole region from the pyramid of Lahûn on the one side, across Rayan to the south, up to the extreme limits of the depression to the south-west. The rim of Jebel el Qatrani has a fairly constant level of about 340 metres above the sea. From Widan el Faras the escarpment trends northwards for a few kilometres before again resuming an easterly direction, which is continued till the well-marked bluff of Elwat Hialla is reached. From this summit the pyramids of Dashûr, Saqâra and Giza are visible to the north, as well as Cairo and the Nile Valley southwards, backed by the bluffs on the Eastern desert limestone plateau.

To the south the isolated peaks of Garat el Gindi and Garat el Faras form conspicuous landmarks on the more or less open plain which stretches to Tamia and the limits of the Fayûm cultivated lands. Eastwards the escarpments continue in a broken irregular manner; the upper ones are gradually lost in an undulating plain, while the lower eventually join those forming the northern part of the ridge separating the Fayûm from the Nile Valley.

WESTERN EXTREMITY OF THE BIRKET EL QURUN.

PART II.

TECTONICS.

SECTION VIII.—FAULTING AND FOLDING.

The Fayûm Depression formed by subaerial Erosion.

More extended examination of the Fayûm region supports my original conclusion[1] that the depression owes its origin to the same causes as have given rise to the other oases-depressions of the Libyan Desert, namely Baharia, Farafra, Dakhla and Kharga[2]. No evidence has as yet been met with which would suggest that earth-movements have played any important part in the formation of the Fayûm depression. Local faults, for the most part of short length and slight throw, occur at certain points, but the influence of these is strictly limited to their immediate neighbourhood. In fact, an examination of the desert margin of the Fayûm conclusively proves that the depression has been cut out through the action of ordinary subaerial denuding agents. The somewhat prevalent idea that the central portion of the depression, that covered by alluvial soil and the water of the lake, is faulted down, also rests on no foundation, all available evidence pointing in an opposite direction. Throughout the margin of the alluvial covered area the Eocene beds forming the surface of the desert can be observed to pass regularly under the cultivated lands; moreover, the same strata are frequently exposed in the bottoms of canals, drains, etc., far within the cultivation. The big drainage ravines of El Bats and El Wadi are, through a large part of their courses, cut down to the underlying Eocene rocks (Ravine beds), and in every locality examined the strata were found in the position they would be expected to occupy if undisturbed by tectonic movements.

Deep Boring at Medinet el Fayûm.

The evidence yielded by the deep boring at Medinet el Fayûm is, as far as it goes, to the same effect. The ground level at the site was at 23·40 metres above sea-level and the following beds were passed through[3] :—

		Metres.
Alluvial clays, clayey sands and sands, the latter in part coarse and pebbly		18·5
Yellow, brown, and grey marls and marly clays (probably belonging for the most part to the Ravine beds)		112·5
Cement coloured stone	Probably these limestones and occasional marls and clays belong to the Rayan series.	43·5
Yellowish stone		6·5
Light brown solid stone		10·5
Cement coloured soft clay...		1·7
Cement coloured stone		12·5
		205·7

Bottom of boring 182·3 metres below sea-level.

[1] BEADNELL. *The Fayûm depression: A Preliminary Notice of the Geology of a District in Egypt containing a new Palaeogene Vertebrate Fauna.* Geol. Mag. Dec. IV, Vol. VIII, No. 450, Dec. 1901, p. 540.

[2] See reports on Kharga Oasis (1900), Farafra Oasis (1901), Dakhla Oasis (1901), and Baharia Oasis (1903), issued by Survey Dept. P. W. M., Cairo.

[3] Public Works Ministry Report. Cairo, 1899.

The method employed in this boring was such as to bring up the material as a ground-up paste, an examination of which does not afford absolutely conclusive evidence as to the age of the rock. The absence, after the first 18·5 metres, of sand or pebbles, common throughout the alluvial deposits of the Fayûm, suggests that the base of these beds was reached at that depth, but from this evidence alone it would perhaps hardly be satisfactory to conclude that the underlying 112·5 metres were entirely Eocene. Considering, however that in the two deep ravines of El Bats and El Wadi the underlying Eocene is very commonly exposed at an average depth of some 15 metres below cultivation level, it is highly improbable that in the centre of the area, at Medinet el Fayûm, the alluvial deposits greatly exceed the same thickness. To classify the 112·5 metres of marly clays as alluvium would give the latter a total thickness of 131 metres and would mean that over an extremely restricted area the Eocene rocks had been denuded to such an extent that the floor of the depression lay 108 metres below sea-level. The ground-up samples of rock closely resemble what might be expected from the clays and marls forming the Ravine beds and in all probability the greater part of the 112·5 metres belong to that series. The harder stone met with at 131 metres, which, with the exception of a band of soft clay, continued down to the bottom, must be regarded as belonging to the underlying Rayan series.

Dr. Blanckenhorn's Fault theory.

Dr. Blanckenhorn, in a paper published in 1901[1] dealing with the Pliocene and Pleistocene of Egypt, describes the Fayûm as a triangular depression bounded on all sides by faults. The position of these bounding faults, as well as of numerous others more or less parallel to the north shore of the Birket el Qurûn, is shown on an accompanying map and in a section drawn from Abshawai to the summit of the plateau north of the lake. Stratigraphical evidence, based on the supposed identity of certain strata in different localities, is brought forward in support of these faults, the author finally stating that the production of the Fayûm is clearly and distinctly to be referred to tectonic movements.

Our conclusion, formed after an examination of the region in some detail, is so diametrically opposed to the above, that it may be worth while to state here the evidence which we consider sufficient to refute the existence of the particular faults described by Blanckenhorn.

Blanckenhorn's fault-lines lie for the most part within the area covered by the alluvial deposits and the water of the lake, so that for want of exposures it is in most cases impossible to directly disprove their existence, although strong presumptive evidence against them can be adduced. The fault along the east side, however, is shown as closely following the junction line of the desert and the cultivated land, but everywhere along this line we found the marls and limestones of the Ravine beds passing regularly from the desert under the cultivated lands, without any sort of break or dislocation. Moreover, an examination of the desert ridge to the east disproved the existence of any faulting on the desert side, while the appearance of the same beds in the ravine of El Bats, a few kilometres to the west, proved the continuity of the beds under the cultivated alluvium in

[1] BLANCKENHORN. *Geologie Aegyptens*, Berlin 1901, Pt. IV, pp. 339-344.
[2] „ p. 341, Fig. 10. Skizze der Strukturlinien des Fayûm.
[3] „ Taf. XIV. Querprofil durch den Fayûmgraben.

this direction. Certainly no fault exists along this side of the Fayûm. Similarly with regard to the fault shown as running from the west end of the lake along the west side of the Fayûm cultivation into the basin of Gharaq; although the desert margin along this side of the Fayûm cultivation has not been so closely surveyed as that on the east side, no evidence in favour of the existence of faults was met with in the particular localities examined. With regard to the third main bounding fault, considered by Blanckenhorn to run throughout the length of the Birket el Qurûn and to be continued eastwards, possibly to the Nile Valley and at least to join the fault on the east side of the cultivation, we need only say that an examination of the desert near Tamia disproves its existence at that end; while it is difficult to imagine that a fault could traverse the lake from end to end without revealing its presence in the island Geziret el Qorn or in one or other of the promontories which jut out so far into the lake from its northern shore. Everywhere the strata are undisturbed and occupy their normal stratigraphical level and position.

Let us finally examine the series of more or less parallel faults stated to exist between the island and the northern shore of the lake, and on the mainland to the north and south of Dimê. Dr. Blanckenhorn publishes a detailed section (op. cit., fig. 2., taf. XIV) showing the positions of these step faults and their effect on the various strata through which they cut. Fortunately, in this neighbourhood the stratigraphical succession is well exposed and the presence or absence of faults become matters of easy determination. The sequence of beds from south to north is normal and uninterrupted and our interpretation of the area is shown in the accompanying sections (Plates XIX, XXII, and fig. 4). We have no hesitation in saying that such faults as those shown on Blanckenhorn's section do not exist. Their insertion appears to be the outcome of an error in the correlation of strata at the three points Abshawai, Geziret el Qorn and Dimê. The bed capping the island is not identical with that forming the plain to the north of Dimê, although shown to be such on the section under discussion.

In a later publication[1] Blanckenhorn admits being in error in his correlation of the different beds in the localities in question and completely withdraws his former statements that the depression owes its existence to fracture and subsidence. The faults shown on his detailed section from Abshawai to Qasr el Sagha are admitted to be non-existent and in this retraction we may presumably include the remainder of the faults described by the same author, as the evidence for them is of a still less satisfactory nature.

In a wind-swept desert area like the Fayûm the slightest dislocations are as a rule markedly obvious, and faults of any magnitude could scarcely escape detection. Over the greater part of the region every bed is laid bare on the surface and can be minutely examined; while the marked irregularity of the escarpments afford sections cut through the different series in every direction. Some areas, however, are covered with superficial deposits, which more or less effectually obscure the underlying rocks; for instance, on the east side a large part of the central floor is hidden by the cultivated alluvium and by the water of the lake; in the south a considerable proportion of the floor of Wadi Rayan is

[1] BLANCKENHORN, *Neue geologisch-stratigraphische Beobachtungen in Aegypten*, S.-Ber. d. math.-phys. Classe d. kgl. bayer. Ac. d. Wiss. Bd. XXX I 1902, Heft III, München 1902, pp. 428, 429.

buried under accumulations of blown sand; and again large areas on the north, west, and south-west sides are obscured by a superficial covering of loose gravel. But as already mentioned, there is no reason to suppose that faults of any importance exist within the areas thus partly obscured. The cultivated lands and the Birket el Qurûn do not occupy low areas produced by faulting but, as shown above, owe their positions entirely to the original northerly dip of the strata and to subsequent erosion.

Numerous small faults effects local.

We have already stated that small local faults occur in various parts of the Fayûm and some of these may be specially mentioned. The most important is about 10 kilometres N.N.E. of Qasr el Sagha; the line of fault lies nearly north-west and south-east, has a length of six or seven kilometres, and affects both middle and upper Eocene beds; at its northern end the fault passes into a fold before finally dying out. Some of the Upper Eocene sandstones are hardened and silicified and form a succession of black knobs along the line of disturbance. To the south of these the axis of dislocation bends slightly eastwards and takes the form of a sharp fold; further south it again becomes a true fault, flanked by a line of highly tilted beds along its south-west side. The effects of this fault are very marked locally but entirely restricted to a limited area. The most important is the breaking of the continuity of the escarpment of the Qasr el Sagha series; the line of cliffs formed by those beds is a very marked topographical feature and the fault in question causes a lateral displacement of seven kilometres.

In the neighbourhood of Qasr el Sagha and westwards for a considerable distance, small strike-faults are of common occurrence in the beds of the Qasr el Sagha series. As a rule these faults do not extend more than a few hundred metres in length, while the down-throw seldom exceeds two or three metres and in almost every case observed is to the north. The hade may be 65° or more. Fig. 1 shows an example near Qasr el Sagha. The most marked of these strike faults is seen to the east of Garat el Esh; commencing a little to the north-east of that hill it runs in a nearly due easterly direction till it cuts the cliffs of the Qasr el Sagha series after some five kilometres. Its down-throw is to the north and never exceeds a few metres; this small throw is however sufficient to cause a marked displacement of the highest bed of limestone forming the dip-slope surface of the plateau at the summit of the Middle Eocene beds.

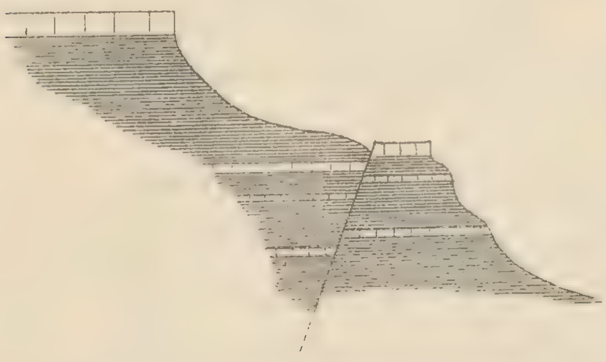


FIG. 1.—Fault near Qasr el Sagha.

At first sight it might be suspected that the very irregular trend of the different escarpments throughout the Fayûm was determined or influenced by fault lines; an extended examination of the cliffs however gave negative results, with one exception; the long narrow hill-mass to the north east of Gar el Gahannem is bounded by faults on both sides and that on the west can be easily traced for seven or eight kilometres northwards, and throughout its length its influence on the topography is very conspicuous.

PART III.

GEOLOGY.

SECTION IX.—GENERAL AND CLASSIFICATION OF STRATA.

THE geology of the area[1] under consideration is almost entirely stratigraphical, the only igneous rocks being more or less local lava flows. The sedimentary rocks of the district have yielded an abundant fauna, both invertebrate and vertebrate; the latter is of unique interest, including as it does a number of highly interesting animal types quite new to science. An extended examination in the field, and comparisons with the stratigraphical succession in other parts of Egypt, checked by the determinations of the fossil molluscan fauna, make it possible to form a very fair estimate of the approximate age of the different rock-stages, although this may necessarily be subject to modification when the specific determinations of the entire collection of organic remains have been completed, and the development of vertebrate life has been correlated and compared with that in other parts of the world.

The depression is cut out in a great series of sedimentary rocks of Middle Eocene, Upper Eocene, and Oligocene age, and one of the features of the stratigraphy of the region is the constancy of many beds over wide areas. The dip of the beds throughout the area is nearly due north and at a very low angle, averaging 2° or 3°, but varying from 1° to 5°; this low dip is very constantly maintained except when locally affected by small faults. The structural geology and tectonics have already been discussed at some length in the previous sections.

The oldest beds found in the depression are the clays, marls, and limestones with *Nummulites gizehensis*, of Middle Eocene age. These are succeeded by a group of white marly limestones and gypseous clays, which largely underlie the cultivated alluvium of the Fayûm. They are followed by a series consisting of clays, sandstones, and calcareous grits, some beds of which are characterized by the abundance of small nummulites and *Operculina*. The latter series is followed by the uppermost truly marine Eocene beds, a group of alternating clays, sandstones and limestones, the "Qasr el Sagha Series" (or Carolia beds), characterized by an abundant invertebrate and vertebrate fauna, and equivalent to the Upper Mokattam beds of Cairo.

Above the Qasr el Sagha series, and well marked off from them both lithologically and palæontologically, is found a great thickness of variegated sands, sandstones, clays and

[1] BEADNELL, *The Fayûm Depression; a Preliminary Notice of the Geology of a district in Egypt containing a new Palæogene Vertebrate Fauna.* Geol. Mag. Dec. IV, Vol. VIII, No. 450, Dec. 1901, pp. 540-546.

marls, the "Fluvio-marine Series" (Jebel el Qatrani beds), divided near the summit by one or more thick intercalated lava sheets, the latter forming a convenient junction line. This series of variegated beds is of Upper Eocene–Lower Oligocene age.

No Miocene strata have been recognized within the area, but further north, as at Mogara, Lower Miocene deposits occur;[1] and it is probable that there is a continuous series of lithologically similar beds from the summit of the Fayûm escarpments (Lower Oligocene) to the Mogara Miocene.

The Pliocene is probably represented by the great terraces of gravel—raised beaches—which are such a marked feature in the geology of the district. Fossiliferous Pliocene deposits have also been recorded from the south part of the area by Schweinfurth.[2]

Pleistocene and Recent are abundantly represented by lacustrine clays, both ancient and modern, alluvial land and blown sand, the formation of which deposits is continuing at the present time.

The following table will show the sequence of strata and the classification adopted in the present memoir :—

TABLE SHOWING SUCCESSION AND CLASSIFICATION OF STRATA IN THE FAYUM.

			Approximate average thickness in metres, north part of Fayum.	
RECENT AND PLEISTOCENE				Alluvial soil, clays, sands, etc. Blown sand. Lacustrine clays, extending to about 23 metres above sea-level.
(MIDDLE ?) PLIOCENE			50	Gravel Terraces (? Pleistocene). Shell-borings on rock surfaces. Fossiliferous deposits of Sidmant.
LOWER OLIGOCENE	TONGRIAN		30	*Fluvio-marine Series (Jebel el Qatrani beds).* Sandstones and sandstone-grits with silicified trees and Basalt sheets, interbedded and contemporaneous.
UPPER EOCENE	BARTONIAN.		250	Variegated sands, sandstones, clays and marls, with limestone-grits and thin bands of limestone. The upper beds contain *Unio* sp., *Lanistes bartonianus*, Blanck., *Turritella pharaonica*, Cossm., *Potamides scalaroides*, Desh., *P. tristriatus*, Lam., *Pleurotoma ingens*, May.-Eym. In the lower beds are large numbers of silicified trees associated with vertebrate remains including *Arsinoitherium Zitteli*, Beadn., *A. Andrewsii*, Lankester, *Palæomastodon Beadnelli*, Andr., *P. minor*, Andr., *Mœritherium Lyonsi*, Andr., *M. trigodon*, Andr., *Megalohyrax eocænus*, Andr., *M. minor* Andr., *Saghatherium antiquum*, Andr. and Beadn., *S. minus*, Andr. and Beadn., *S. magnum*, Andr., *Ancodus Gorringei*, Andr. and Beadn., *Geniohyus mirus*, Andr., *G. fayumensis*, Andr., *G. major*, Andr., *Phiomia serridens*, Andr. and Beadn., *Pterodon africanus*, Andr., *P. macrognathus*, Andr., *Eremopezus libycus*, Andr., *Testudo Ammon*, Andr., and frequent crocodilian and chelonian remains.

[1] ANDREWS, *Fossil Mammalia from Egypt*, Geol. Mag. 1899, No. 425, pp. 481, 482; and BLANCKENHORN, *Neues zur Geologie und Paleontologie Ægyptens*, III, Das Miocân," Zeitschr. d. Deutsch. geol. Gesellschaft. Jahrg. 1901, pp. 98-101.

[2] SCHWEINFURTH, *Reise in das Depressionsgebiet im Umkreise des Fayum*, Zeitschr., Ges. f. Erdkunde, Berlin, No. 122, 1886, p. 100.

TABLE SHOWING SUCCESSION AND CLASSIFICATION OF STRATA IN THE FAYUM (*continued.*)

			Approximate average thickness in metres, north part of Fayum.	
MIDDLE EOCENE	PARISIAN.	UPPER MOKATTAM	155	*Qasr el Sagha Series* (*Carolia beds*). Alternating limestones, marls, clays and sandstones with *Qerunia* (*Hydractinia*) *cornuta*, May.-Eym., *Astrohelia similis*, Felix., *Echinolampas Crameri*, Loriol., *Ostrea Reili*, Fraas, *Ostrea elegans*, Desh., *Alectryonia Clot-Beyi*, Bellardi, *Exogyra Fraasi*, May.-Eym., *Carolia placunoides*, Cantr., *Cardita fajumensis*, Oppenh., *Macrosolen Hollowaysi*, Sowerby, *Turritella pharaonica*, Cossm., *T. carinifera*, Desh., *Mesalia fasciata*, Lam., *Rimella rimosa*, Sol. The vertebrate remains include *Mœritherium Lyonsi*, Andr., *M. gracilis*, Andr., *Barytherium grave*, Andr., *Eosiren libyca*, Andr., *Zeuglodon Osiris*, Dames, *Gigantophis Garstini*, Andr., *Pterosphenus Schweinfurthi*, Andr., *Psephophorus eocœnus*, Andr., *Thallassochelys libyca*, Andr., *Podocnemis antiqua*, Andr., *P. Stromeri*, v. Rein., *Stereogenys Cromeri*, Andr., *S. podocnemioides*, v. Rein., *Tomistoma africanum*, Andr., with siluroids and *Propristis Schweinfurthi*, Dames.
		LOWER MOKATTAM	50	*Birket el Qurûn Series* (*Operculina-Nummulite beds*). Sandstones and clays, with sandy limestones, and one or more well marked concretionary sandstones weathering into large globular masses. *Nummulites Fraasi*, de la Harpe, *N. Beaumonti*, *Operculina discoidea*, Schwag., *Qerunia cornuta*, May.-Eym., *Plicatula polymorpha*, Bell., *Pectunculus pseudopulvinatus*, Orb., *Cardita Viquesneli*, d'Arch., *Cardium Schweinfurthi*, May.-Eym., *Venus plicatella*, May.-Eym., *Macrosolen Hollowaysi*, Sow., *Lucina pharaonis*, Bell., *Tellina scalaroides*, Lam., *Clavellithes longævus*, Sol., *Voluta arabica*, May.-Eym., *Turritella pharaonica*, Cossm., *T. carinifera*, Desh., with *Zeuglodon Osiris*, Dames, and *Z. Isis*, Beadn.
			70	*Ravine Beds.* White marls and marly limestones with gypseous clays; *Nucularia* sp. *Leda* sp., *Corbula* aff. *pixidicula*, Desh., *Lucina* sp. (? *pharaonis*), *Tellina tenuistriata*, Desh., *Zeuglodon Isis*, Beadn., and scales and teeth of fish.
			130	*Wadi Rayan Series* (*Nummulites gizehensis beds*). Limestones, marls, clays, etc., with *Nummulites gizehensis*, Ehrbg., *N. curvispira*, *Carolia placunoides*, Cantr.

SECTION X.—MIDDLE EOCENE (PARISIAN).

A.—**Wadi Rayan Series.**—(*Nummulites Gizehensis Beds*).

(A.I.e. Schweinfurth, I.b. Mayer-Eymar,[1] Lower Mokattam of Cairo).

Beds of this group are chiefly found in the south of the depression. The wadis Rayan and Muêla, as already shown by Schweinfurth and Mayer-Eymar[2], are cut out in clays and limestones of Lower Mokattam age; the upper beds of limestone, containing among other

[1] Op. cit. pp. 108-110.

[2] *L'Oasis de Moëleh*, Bull. de l'Institut Egypt.. Fasc. 3, Ap. 1892.

fossils[1] numerous examples of the large *Nummulites gizehensis*, form the greater part of the floor of the depression west of the Fayûm cultivation, stretching from Jebel Rayan to the foot of Gar el Gehannem,[2] 28 kilometres west of the western end of the Birket el Qurûn (Section XX). Near the latter hill examples of *N. gizehensis* of inordinately large size occur.[3]

At the conical hill at the southern entrance to Wadi Muêla the following beds were noticed:—

Top of hill.

1. Hard white limestone with small nummulites, *Lucina, Callianassa*, and echinids. Salt occurs in thin deposits along joint-planes. The lower part of this bed is largely composed of small nummulites and bryozoa. This generally white limestone passes down into
2. Brown, usually sandy, limestone with oysters and small nummulites. In it are intercalated thin beds of greenish brown sandstone and clayey sand with impressions of bryozoa. Some of the brown sandy limestones are full of small nummulites. *Ostrea* and *Carolia* numerous. The beds are not constant, the clayey sandstones passing insensibly into sandy limestones.
3. Softer beds with large nummulites, corals, *Ostrea, Nautilus.*
4. Soft green and brown clays, with occasional oyster-beds.

At the corner of the cliff 7½ kilometres N.N.W. of the monastery of Der el Galamûn, in Wadi Muêla, occur about 80 metres of hard white nummulitic limestones, with beds of argillaceous sandstone and sandy clays. Fossils are numerous and include nummulites of several species (*N. gizehensis*, etc.), *Carolia placunoides*, different species of *Ostrea*, with gastropods (among others *Terebellum sopitum*), bryozoa, etc. It is very noticeable that the nummulites, especially the small species, occur in remarkable profusion not only in the limestones but often in the clays.

The following section will give a good idea of the general alternations found in this area; it was measured at Jebel Rayan,[4] 24 kilometres west of the western end of the cultivation of Gharaq basin.

Top of plateau.	Metres.
1. Hard snow-white limestone with occasional nummulites passing down into hard highly nummulitic limestone; *N. gizehensis, Ostrea* sp., *Lucina* sp. *Mitra* sp., and *Carolia placunoides* occur among others	31
2. Vertical-faced bed of greenish clayey sands and sandy clays (glauconitic) with *Carolia, Ostrea* and *Nummulites.* Near top of bed there is much gypsum. The nummulites in this bed are often collected together so as to form hard concretionary masses; these masses, by becoming more numerous, finally form a hard bed of nummulitic limestone intercalated in the clays near the top. The junction of the clays with the limestone of Bed No. 1 is very irregular	16
3. Greenish shelly sands and sandy clayey bands, interbedded with impure chalky nummulitic limestones with *N. gizehensis, N. curvispira*, and a third smaller species; *Ostrea* sp. This bed is much obscured by debris	11
4. Hard slate-blue shales, weathering to paper-shales	2

[1] The following may be mentioned; *Euspatangus* (*formosus?* and *Blanckenhorni*), *Schizaster*, *Lobocarcinus* (*? Paulino Wurtembergicus*), *Nautilus* sp. etc.

[2] El Haram el Bahrl of Schweinfurth.

[3] Individuals of 60 mm. diameter are not uncommon.

[4] Cape Rayan of Schweinfurth.

ALLUVIAL DEPOSITS OVERLYING MARLY LIMESTONES (RAVINE BEDS) IN EL WADI, RAVINE NEAR QASR GEBALI.

5.	Brownish marls passing up into clays	2
	Limestone band largely made up of small and large nummulites and echinids	1
	Glauconitic (?) and clayey sands and sandy clays, with *Ostrea*, *Carolia*, and nummulites, weathering with a vertical face. In some bands large numbers of small and large nummulites lie embedded in every position, as if tossed about by currents during the process of becoming buried by sediment. Gypsum occurs in thin veins and often encloses the nummulites...	36
6.	Hard markedly-white nummulitic limestone full of *N. gizehensis* and other species (*N. curvispira*, etc.); the rock usually has a dark brown colour when freshly fractured. A shelly band rich in corals occurs nine metres from the top. The upper part is more marly and less nummulitic than the rest of the bed. Base invisible. ...	30
	Total thickness of beds in the above section	129

The following is a section of the beds exposed in Wadi Muêla compiled from a paper by Mayer-Eymar on this oasis :—

Top.			Metres.
PARISIAN.	Id.	White siliceous cavernous limestone with *Lucina globulosa*, Desh., *Gisortia*, *Rostellaria*, *Eschara Duvali*, Michelin., (Probably ≡ bed No. 1 of our J. Rayan section)..	10
		Greyish-yellow marl, rich in places with *Ostrea Gumbeli, Pecten mœlehensis*, May.-Eym., *Vulsella chamiformis*, May.-Eym., *Velates Schmiedeli*, Chemnitz, *Cerithium fodicatum*, *Pleurotoma*, *Borsonia*, *Fusus*, *Rostellaria*, etc.... ...	6
		Yellowish sandy marl, with small nummulites.	
	Ic.	Yellowish marls, divided by one or two bands of red clay, with *Nummulites gizehensis*...	7
		Hard bedded clay	1
		Vari-coloured gypseous marls...	4
		(Probably ≡ beds 2, 3, 4 at J. Rayan).	
	Ib.	Very hard, rich greenish-grey, siliceous limestone with *N. gizehensis, Pecten corneus*, J. Sow., and *Lucina* (*L. consobrina*, Desh., and *L. Defrancei*, Desh.).	4 to 5
		(Probably ≡ upper part of bed 5 at J. Rayan.)	

There is a considerable difference in thicknesses between the above section and that of Jebel Rayan. Our heights agree closely with those of Schweinfurth, so that it is probable that Mayer-Eymar is in error, notwithstanding his challenge of Schweinfurth's figures in the paper mentioned.

B.—Ravine Beds.

The beds of this series, consisting of gypseous clays, clayey marls, and white marly limestones, are met with bordering the cultivation on the east, west and north sides; they pass under the alluvial soil of the cultivated land and are frequently seen in the bottoms of canals, and especially in the deep ravines known as El Bats, and El Wadi (Plates III and V). The relation of these beds to the Rayan series below is well seen at the prominent outstanding hill Gar el Gehannem (Fig. 2); here the plain to the east and south is formed of the uppermost member of the Wadi Rayan series, a limestone full of *Nummulites gizehensis*. In the hill itself the latter is directly overlain by gypseous and glauconitic

sandy clays and marls, with hard intervening beds of yellowish, often marly, limestone. The upper beds consist of alternating clays, sandy limestone and sandstone, at the top being

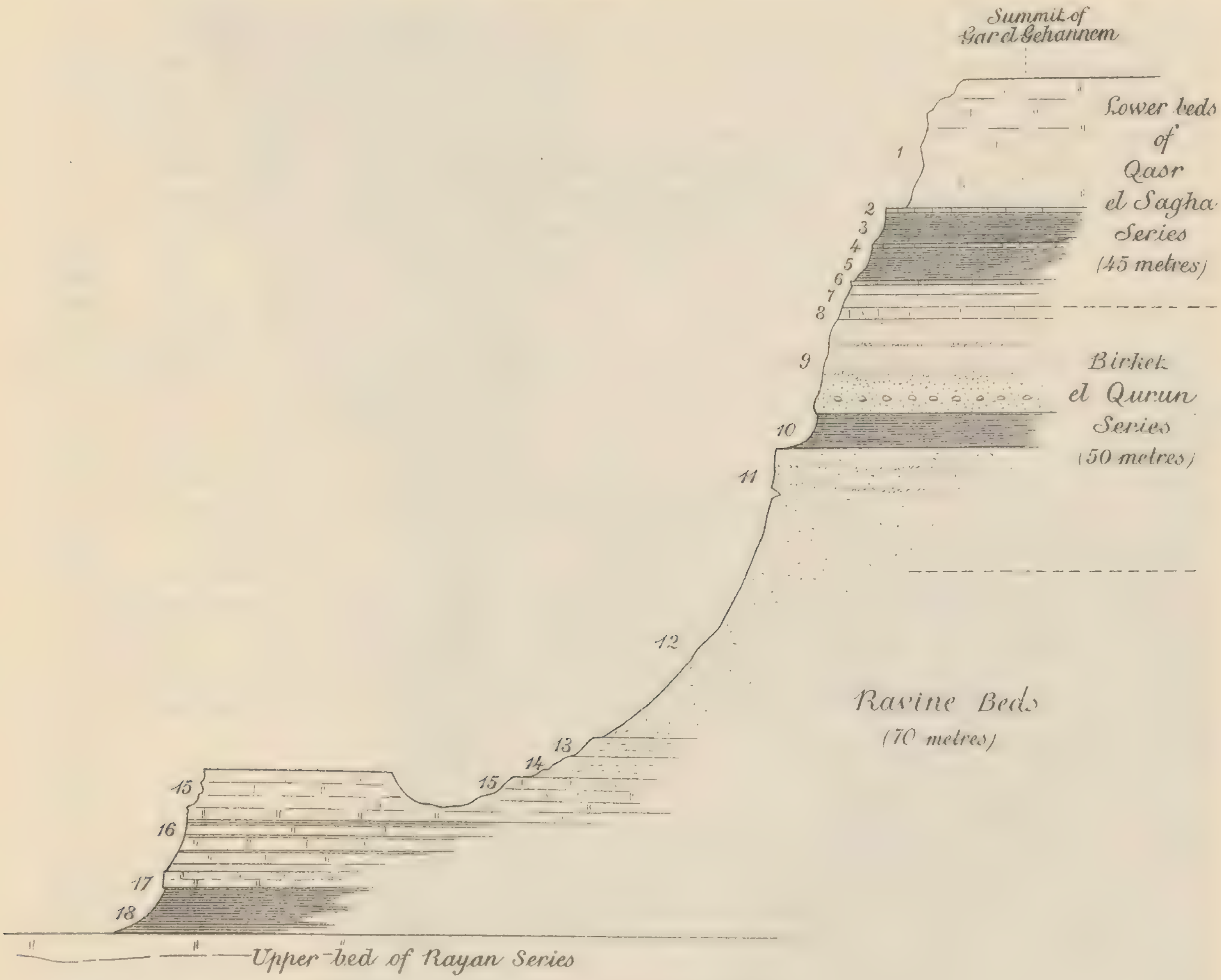


FIG. 2.—Section at Gar el Gehannem, showing the relation of the Wadi Rayan Series to the Ravine Beds.

a thick bed of the latter passing up gradually into the sandstones of the Birket el Qurûn series. The following is the detailed section:—

Summit of Gar el Gehannem.		Thickness in metres.
1. Hard yellow and white limestone crowded with shells, chiefly large individuals of *Carolia placunoides* and *Ostrea Fraasi*. Numerous nummulites in upper part...	Lower beds of Qasr el Sagha Series (45 metres)	25
2. Limestone full of *Turritella carinifera*, *Ostrea Clot-Beyi*.		1
3. Brown clays.		6
4. Shelly limestone with *Carolia*, *Turritella*, *Ostrea*, *Cardita* and *Qerunia* (*Hydractinia*)		1
5. Greenish clays		6
6. Nummulitic limestone with *Carolia*, *Qerunia* and four species of *Turritella*... ...		$1\frac{1}{2}$
Light blue clays		2
7. Light green and brown sandstone with irregular concretions		$2\frac{1}{2}$

8.	Brown shelly limestone full of *Carolia placunoides*, *Ostrea Reili*, *O. Fraasi*, *Turritella*, *Balanus* and nummulites	Birket el Qurûn Series. (50 metres)	2
9.	Yellow sandstone with bands of shelly limestone crowded with nummulites, oysters, etc. Near top casts of *Cardita, Carolia;* also *Cerithium*, *Teredo*, *Ostrea*, *Pecten*, *Pinna*, and echinids. Calcareous concretions near base		18
10.	Clays with much gypsum...		6
11.	Yellow sandstone with *Balanus*. Bands crowded with two species of nummulites and occasional oysters. In places the foraminiferal bands become highly calcareous. Below similar, with hard compact grey bands and occasional fish-spines and teeth		24
12.	Similar to above, with numerous casts of *Cardita*, etc., and small *Ostrea*	Ravine Beds (10 metres)	24
	Argillaceous sandstone with thick stockwork of gypsum and calcareous nodules.		6
13.	Light yellow, brown, and greyish gypseous clays		3
14.	Yellow-brown sandstones and sandy limestones, often argillaceous. Fish-scales. Brown clays		
	Yellow-white marls and marly limestone		5
15.	Hard light yellow shelly limestone, in part marly, in part sandy		10
16.	Ochreous-yellow, grey, and white clays and marls with gypsum		9
17.	Hard yellow-white shaly marl with numerous shell-impressions; much gypsum...		3
18.	Yellow marly clays; soft yellow and grey-brown clays, dark sandy glauconitic, yellow, and black, clays. *Zeuglodon* remains fairly common. Shell impressions. Much gypsum		
	Fairly hard yellow-white glauconitic marl.		10

Marly limestone with *Nummulites gizehensis* forming top of Rayan beds.

The clays, marls, and limestones of the Ravine beds are generally found to contain fairly numerous shell-impressions, including *Nucularia* sp., *Leda* sp., *Cardita* sp., *Corbula* aff. *pixidicula*, *Lucina* sp., *Oudardia ovalis*, Desh., *Tellina tenuistriata*,[1] numerous small fish-scales, and occasional large teeth of sharks; while the skeletons of the toothed-whale *Zeuglodon Isis* are fairly common, although usually in poor preservation.

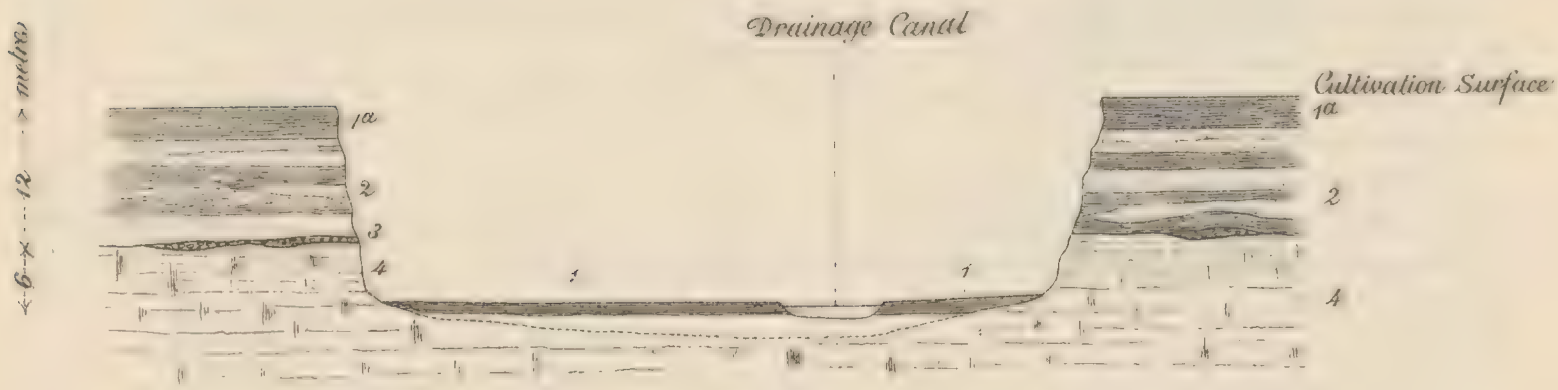
In the ravine of El Bats, about one kilometre west of Sêla, these beds (5–6 metres thick) are seen unconformably overlaid by 12 metres of false-bedded gypseous sands and clays passing up into the superficial cultivated loam. The junction of these alluvial deposits and the underlying Eocene is distinctly unconformable and an intervening pebble-bed is occasionally present (Fig 3).

In the large ravine known as El Wadi, which traverses the west side of the cultivation of the Fayûm, these beds are frequently well exposed; their lithological characters remain very constant. Here, as in El Bats, they are unconformably overlain by a varying thickness of Pleistocene and Recent clays. Their surface, a plain of subaerial denudation, represents the original floor of the depression before the entry of the sediment-carrying water from the Nile Valley through the Lahûn gap; its irregularity is seen in Plate V.

The plain bordering the cultivation to the east of Sêla and Rubiat likewise consists of these same white marls with fish-scales, etc.; they pass regularly under the cultivated land.

[1] BLANCKENHORN, *Neues zur Geologie und Palæontologie Ægyptens* (II. Das Palæogen) Zeitschr. d. Deutsch. Geolog. Gesellschaft, Jahrg. 1900, p. 446, has determined this as *T. tenuistriata*. He refers to these beds as corresponding to the Tafla of Jebel Mokattam, but I regard them as probably representing a considerably lower horizon.

Shaly marls, gypseous clays, and chalky limestones of the same age are seen in, and to the south of, the railway crossing the desert between Sêla and Medum. Eastwards they stretch into the Nile Valley, being found exposed along the desert-edge bordering the cultivation at Medum, Nawamis and Masaret-Abusia.



RECENT AND PLEISTOCENE:
1. Marsh and poorly cultivated land.
1*a* Cultivated loam.
2. Sands and clays, with gravelly bands; often concretionary and gypseous beds.
3. Pebble-bed marking unconformable junction.

MIDDLE EOCENE — RAVINE BEDS-:
4. Gypseous saliferous marly clays, white marls and limestone with fishscales and *Tellina Corbula*, etc.

FIG. 3.—Sketch-Section across *El Bats*, 1 kilometre West of Sêla.

The same beds are exposed immediately to the east of the village of Sersena, midway between Sêla and Tamia. They are again well seen in the ravine below the last named village, and forming the narrow strip of the desert projecting into the cultivation as far as the northern end of the Tamia lake; they also occur on the shore of the latter at El Tuba, about 2 kilometres south of the village. At Tamia their exposure measures 25 metres in thickness.

At various points along the north side of the Birket el Qurûn exposures of this series occur, the beds forming the lower sloping part of the cliffs overlooking the lake, as well as the base of the island "Geziret el Qorn," although only the upper beds are visible above the water of the lake. Both here and along the northern shore of the lake they are for the most part hidden by the high level recent lacustrine clays, but where occasionally exposed their identity is certain, the characteristic small brown fish-scales being abundant, besides occasional teeth, with shell-impressions of the different genera enumerated above.

ESCARPMENT OF THE BIRKET EL QURUN SERIES NEAR THE WESTERN END OF THE LAKE.

At the western end of the lake the Ravine beds form the lower part of the cliff as well as the plain to the south; the underlying *Nummulites gizehensis* limestone not being exposed. The series consists of some 45 metres of white and grey shaly marls with harder bands of siliceous limestone intercalated throughout, one of which usually forms the uppermost bed. It is, in fact, the development in places of one or other of these hard beds of limestone near the top of the series that gives rise to the bold promontories, or horns, which occur on the north side of the Birket el Qurûn.

The greater part of the marls and clays met with from 18·5 to 112·5 metres below the surface in the boring at Medinet el Fayûm in all probability belong to the Ravine beds.

The maximum thickness of this series is 70 metres, measured at Gar el Gehannem.

C.—**Birket el Qurun Series** *(Operculina-Nummulite Beds).*

The above designation is convenient and applicable to these beds, which form the escarpment immediately overlooking the lake on the north side throughout its length.

The group includes all the beds between those last described and the well-marked Qasr el Sagha series, homotaxial with the Upper Mokattam (the brown beds) of Jebel Mokattam, near Cairo. It thus appears to be the equivalent of the upper part of the white beds (quarried limestones) of the Mokattam section, although the lithological characters are entirely different, the massive limestones of Jebel Mokattam being represented in the Fayûm by an arenaceous and argillaceous series, deposited probably in water of far less depth. Where the different members of this series are well exposed certain beds are found to be characterized by the abundance of two foraminifera, the one a small thin-shelled *Operculina* (*O. discoidea*), and the other a small thick nummulite.[1] The tests of these foraminifera sometimes make up entire bands of rock. In addition, the series includes certain beds which at times become very fossiliferous, and contain a well-preserved molluscan fauna.

The series is well seen in the desert separating the Fayûm from the Nile Valley; on the south-east and east sides of the former; along the northern boundary of the cultivation and the Birket el Qurûn; and westwards in the cliffs to beyond the outlying hill-mass of Gar el Gehannem.

The following section was measured on the south-west of the Fayûm, from Ezba Qalamsha (on the confine of the cultivation) to the ridge summit 5 kilometres to the south-east.

Top.

Summit of ridge 5 kilometres south-east of Ezba Qalamsha.

Pliocene Raised Beach with occasional *Ostrea cucullata*, Born., made up of gravels with blocks of limestone.

[1] The nummulites from the Birket el Qurûn series have not yet been critically examined. There appear to be several species present, including *N. Beaumonti*, *N. Sub-Beaumonti*, *N. Fraasi* and *N. Schweinfurthi*. In the Zeuglodon Valley, 12 kilom. W. S. W. of Gar el Gehannem, occasional individuals of *N. gizehensis* occur in the basal beds. As there appears to be some doubt whether the four smaller nummulites mentioned above are specifically distinct we shall not attempt to discriminate too closely in the present report.

		Metres.
Birket el Qurun Series.	1. Ochre-coloured calcareous sandstone and sandy limestone crowded with foraminifera (*Nummulites Fraasi*, etc.), *Ostrea*, etc.	38
	2. Sandy limestone, largely made up of foraminifera (*Operculina discoidea* ?)	2
	3. Sandy shale	2
	4. Sandstone, partly calcareous, with much gypsum	3
	5. Calcareous sandstone with concretionary weathering	17
	6. Shale with gypsum	2
	7. Calcareous sandstone	4
	8. Shale with gypsum	2
	9. Calcareous sandstone, hard and yellowish...	2
	10. Gypseous shale with numerous small shells (*Tellina* sp.) passing down into sandy limestone. (This bed is the uppermost member of the Ravine beds)	6
Base, cultivation level.	Total thickness	78

To the north of the Lahûn pyramid the beds agree generally with the above. The following are the chief divisions here:—

Top of Hills.	Metres.
Gravel Terrace (Pliocene) 22 metres thick.	
1. Calcareous sandstone and sandy limestones full of nummulites; also *Ostrea*, etc....	31
2. Ochre-coloured calcareous sandstone or sandy limestone, often crowded with *Operculina discoidea* and some *Nummulites Fraasi*, etc.	12
3. Sandy limestone with small foraminifera at top and some shells. The upper part of this bed has been quarried	20
4. Shales and shaly limestone; gypsum	—
Total thickness	63

The foraminiferal sandy limestones of this series are seen at points in the desert bounding the eastern margin of the cultivation, notably east of Sersena and at the top of the hill 15 kilometres north-east of Rubiat.

The following section was measured at the prominent hills 17 kilometres 28° N. of E. (magn.) of Tamia:—

	Metres.
1. Greyish laminated sandy clays with gypsum; *Ostrea* band near top	7
2. White sandy limestone with numerous badly preserved *Ostrea*, *Pecten*, and other lamellibranchs...	1
3. Dark-brown clayey sands with gypsum and grey sandy clays with obscure plant-remains. Occasional *Ostrea*	14
4. Hard, white, sandy limestone with numerous *Ostrea* at top; soft clays with gypsum...	1
5. Greenish and brownish sands and sandy clays with band of sandy limestone near top... 6. Greyish-brown, impure, sandy limestone weathering into large globular concretions. Shell impressions	14
7. Sandy clays and marls alternating with impure limestones; much gypsum. Occasional fish-remains and small oysters... 8. Greenish sandy limestone with traces of shells	22
9. Finely laminated grey-brown clays with black carbonaceous matter and fish-remains; saliferous	3
10. White sandy limestone	1
11. Soft yellow sandstones, etc. 12. White marls with fish-scales, etc.; base not seen. (This bed, and possibly also 9, 10, 11, should be reckoned as belonging to the Ravine beds)	7
Total thickness...	70

In the north of the Fayûm the series is characterized by the presence of one or more very constant well-marked beds of hard calcareous sandstone, which almost invariably weather into huge globular masses. These masses should be regarded as huge weathered-out concretions, rather than as water-rounded blocks, although no doubt in many cases their roundness has been increased by the action of the waters of Lake Moeris as the level of the latter gradually fell, and possibly still earlier during the invasion of the Pliocene sea; from the latter time also may date the millions of parallel vertical borings with which these and other exposed rocks are often perforated. In the various places where one of these beds forms the present surface of the desert the concretions may be seen in different stages of exposure, from the initial, where only just the tops are laid bare, to the final stage where the globes are left completely weathered out, as seen in the illustration (Plate VII). The appearance of the desert when covered for many square kilometres with thousands of these blocks is more easily imagined than described.

The lower beds of the Birket el Qurûn series form the island Geziret el Qorn, and consist of clays and sandstones containing a considerable number of organic remains. These beds were collected from and examined by Schweinfurth [1] in 1879, the mollusca being subsequently described by Mayer-Eymar,[2] while the vertebrate remains, which included cetacean bones and numerous fish-teeth, were submitted to Dames.

The following species were determined by Mayer-Eymar, who indicated that the fauna as a whole had a Bartonian aspect [3]:—

UPPER BED.

Ostrea plicata, Defr.
Arca Edwardsi, Desh.
Lucina pomum, Duj.[4]
Lucina cfr. *tabulata*, Desh.
Cardium Schweinfurthi, May.-Eym.
Cytherea Newboldi, May.-Eym.
Tellina pellucida, Desh.
Mactra compressa, Desh.
Corbula pyxidicula, Desh.
Calyptræa trochiformis, Lam.
Turritella angulata, Sow.
Ficula tricarinata, Lam.

LOWER BED.

Astrohelia similis, May.-Eym.
Goniastræa cocchii, d'Achiardi.
Heliastræa acervularia, May.-Eym.
Heliastræa Ellisi, Defr. (*Astræa*).
Heliastræa flattersi, May.-Eym.
Ostrea digitalina, Dubois.
Ostrea gigantea, Sol.
Ostrea longirostris, Lam.
Ostrea producta, Delb. et Raul.
Isocardia cyprinoides, Braun.
Turritella carinifera, Desh.
Turritella transitoria, May.-Eym.
Turritella turris, Bast.
Turbo Parkinsoni, Defr.
Pleurotoma, sp.

[1] SCHWEINFURTH, op. cit. p. 139.

[2] ZITTEL, Palæontographica N.F.X. 3 (XXX) *Die Versteinerungen der tertiäre Schichten von der westlichen Insel im Birket el Qurun See*, von Prof. Karl Mayer-Eymar.

[3] It must be mentioned here, however, that more recently Mayer-Eymar speaks (*Nouvelles Recherches sur le Ligurien et le Tongrien d'Égypte*, Bull. Inst. Égypt., April, 1894, p. 216) of the Mokattam beds above Qasr el Sagha, some 100 metres higher in the series, as Parisian, but does not explain these two conflicting determinations. It seems quite certain, however, that these island beds are of Parisian age, and not Bartonian as stated by him.

[4] *Lucina pharaonis*, Bell., (*L. pomum*, May. Eym. not Dujardin) see Oppenheim, *Zur Kenntnis alttertiärer Faunen in Ægypten*, Palaeontographica, Bd. XXX, III, p. 124.

The cetacean remains, belonging to the genus *Zeuglodon*, were described by W. Dames,[1] who compared them with the American species *Z. macrospondylus* and *Z. brachyspondylus*, but did not then consider them to represent a new species; in a later publication,[2] however, the same author described similar but more complete remains, also collected by Schweinfurth (from beds belonging to our Qasr el Sagha series), as a new species, *Z. Osiris*. A considerable number of fish-remains from Geziret el Qorn are also described in the earlier publication. Although the difference in size of the bones of separate individuals was considered by Dames to be sexual, it seems probable that there are two distinct species of *Zeuglodon*, as the smaller type appears to have a much greater upward range than the larger[3]; both species, *Z. Osiris*, and *Z. Isis* occur in the Birket el Qurûn series, and a very fine mandible of the larger was obtained from these beds in the cliffs near the west end of the lake.[4] More recently a third species has been discovered by Stromer and described under the name of *Z. Zitteli*.[5]

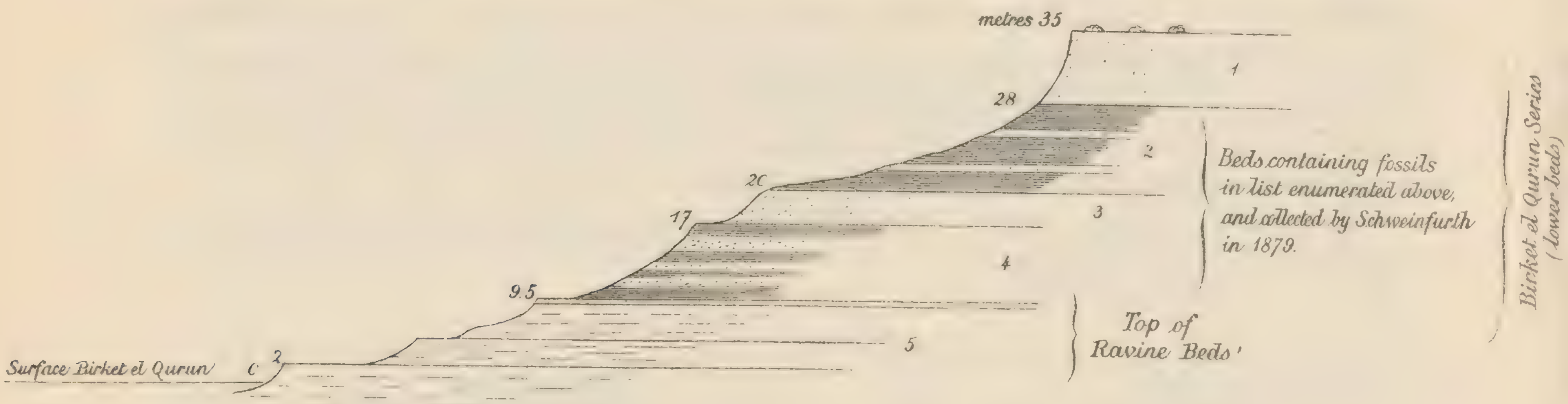


FIG. 4.—Profile of beds of Geziret el Qorn.

1. Hard brown sand-rock with large concretions of weathered globular sandstone on the summit; ferruginous nodular bands containing shell-casts occur near top. 2. Soft gypseous clays with bands of sand-rock and sandstone with *Ostrea*, *Cardium Schweinfurthi*, *Turritella*, corals, *Zeuglodon*, chelonian and fish-remains. 3. Brown sand-rock. 4. Soft gypseous clays and harder brown sandstones. 5. White shaly marl with fish-scales; hard band at top and soft sandy shaly clays below.

The surface-slope is much less than shown in sketch and is generally covered by a deposit of lacustrine clays containing freshwater shells and fish-bones.

The accompanying profile (Fig. 4), measured during a hurried visit to the island for the purpose of correlating these beds with those of the mainland, shows the character of the lower beds of the Birket el Qurûn series at this point.[6]

[1] DAMES, *Uber eine Tertiäre Wirbelthier Fauna von der westlichen Insel des Birket el Qurun in Fayum (Ægypten)*, Sitzungsber. Akad. Wissensch., Berlin, 1883.

[2] *Uber Zeuglodonten aus Ægypten und die Beziehungen der Archæoceten zu den übrigen Cetacean,* Palæontologische Abhandlungen von W. Dames und Kayser, I. V. 5, Jena, 1894.

[3] We propose to refer to this species as *Z. Isis*. See Geol. Mag. No. 479, Dec. V, Vol I, No. V, May 1904, p. 214.

[4] See also, Stromer von Reichenbach, *Zeuglodonten-Reste aus dem oberen Mitteleocän des Fayum*, Bayer Akad. Wissensch. Bd XXXII, 1902, pp. 341-352.

[5] ERNEST VON STROMER. *Zeuglodon-reste aus dem oberen Mitteleocän des Fayum*, Beiträge zur Paläontologie und Geologie Osterreich-Ungarns und des Orients. Band XV. Heft II and III, p. 82.

Also *Einiges über Bau und Stellung der Zeuglodonten*, Zeitschr. d. Deutsch. geolog. Gesellsch. Jahr. 1903.

Compare Fraas *Neue Zeuglodonten aus dem Unteren Mitteleocän vom Mokattam bei Cairo,* Geol. u. Palœont. Abhand. Neue Folge Band VI Heft 3. Jena 1904.

[6] As the fossils occurring in these beds had been collected and described by Schweinfurth, Dames, and Mayer-Eymar, the writer did not spend further time on the island than was necessary for correlating the beds with his classification.

WEATHERED CONCRETIONARY SANDSTONE (BIRKET EL QURUN SERIES) ON NORTH SHORE OF LAKE, NEAR GEZIRET EL QORN.

The upper beds of the Birket el Qurûn series in this part of the Fayûm are lithologically similar to those just described, consisting of alternating clays and sandstones, about 37 metres thick. They are, however, generally much richer in fossil remains, which are likewise usually better preserved than in the lower beds. Some of the brown sandstones of this series are literally crowded with perfect examples of many of the typical mollusca; and further west, near the end of the lake, foraminiferal bands again become noticeable. Near Dimê the escarpment of these and the lower beds is gentle and inconspicuous, but followed westwards it becomes a bold precipitous cliff, increasing in height towards the western end of the lake, where it is capped by the lower beds of the Qasr el Sagha series.

The following section was measured on the mainland[1] opposite the island Geziret el Qorn.

	Metres.
Top.	
1. Gypseous clays, separated by a band of brown sandstone crowded with white well-preserved shells, including numerous individuals of *Plicatula polymorpha*, *Ostrea*, *Turritella* and *Lucina pharaonis*. Large vertebrae of *Zeuglodon Isis* occur on this horizon further to the north-east	8
2. Sandstones and gypseous clays. Although here the sandstones are not hard or predominant, this bed is equivalent to the hard sandstone full of borings capping the plain between the ruins of Dimê and the top of the escarpment overlooking the lake. Further north this bed often contains numerous *Carolia placunoides* and *Ostrea*.	3
3. Gypseous clays	3
4. Clays, brown sandstones, and occasional beds of limestone, often very fossiliferous, containing *Ostrea Reili*, *Carolia placunoides*, *Cardita Viquesneli*, *d'Arch.*, *Lucina* sp. *Turritella pharaonica*,[2] *Clavelithes longævus*, *Qerunia cornuta*, etc., etc.	10
5. Clays with fossils as in last bed, capped by hard band of shelly sandstone	3
6. Alternating yellow-brown sandstones and gypseous clays	10
Total thickness...	37

Bed with weathered-out sandstone concretions at top = upper bed of section at Geziret el Qorn.[3]

At the western end of the Birket el Qurûn the series is well marked, the sandstone beds forming the steep face of the bold precipitous cliffs which are so marked a feature at this end of the lake. The group has a thickness of some 50 metres and is overlain by the lower beds of the Qasr el Sagha series; it is more convenient here to give the entire section of the cliffs down to the base of the series under discussion:—

[1] Cossmann has recently described some Middle Eocene shells collected from the same locality, near Dimê, in a publication entitled *Additions à la Faune Nummulitique d'Égypte*, le Caire, 1901.

[2] *T. pharaonica*, Cossmann. A new species; apparently this is the form quoted by Blanckenhorn and Mayer-Eymar as *T. angulata*. According to Cossmann, however, *T. pharaonica* differs from *T. angulata* in several particulars, especially in being more thickset.

[3] Blanckenhorn, thinking that the bed capping the island of Geziret el Qorn is identical with that forming the plain around and to the north of Dimê, has, in a section recently published (*Neues zur Geol. u. Palænt. Ægyptens, IV. Das Pliocän*, etc., Zeitschr. d. Deutsch. geol. Gesellsch., Jahrg. 1901, Taf. XIV, fig. 2), inserted a number of faults letting the beds down continually to the south. The beds however are not identical, and no faults occur.

		Metres.
Top of Cliffs.		
1.	Hard grey sandstone and shelly limestone passing up into calcareous sandstone (forming surface of plain dipping north).	Lower part (42 metres) of Qasr el Sagha Series.
2.	Impure sandstone with numerous fossils:—*Qerunia cornuta*, corals, *Ostrea Reili*, *O. Clot-Beyi*, *Carolia placunoides*, *Plicatula polymorpha*, *Cardita*(? *fajumensis*) sp., *Clavelithes longævus*, *Serpula*, etc.	
3, 4.	Clays with band of argillaceous sandstone. Septaria bed near base. Fish-remains.	
5.	Earthy limestone crowded with *Ostrea Clot-Beyi*, *O.* sp., *Plicatula polymorpha*, *Pecten* sp., *Lucina* sp., *Cytherea* sp., *Turritella* sp., *Nonionina* sp., *Oliva* sp., *Pleurotoma* sp., *Vermetus* sp., *Nautilus* sp.	
6.	Thin-bedded clays, grey with yellowish band, sandy clays interbedded with soft whitish sandstones with small irregular concretions. Clays, gypseous and sometimes carbonaceous.	
7.	Shelly sandstone, hard on upper surface and very fossiliferous (forms similar to Bed 9).	
8.	Gypseous clays.	
9.	Thin (·25 to ·5 metre) hard dark reddish-brown, very ferruginous, concretionary-weathering sandstone with nummulites and *Operculina* and well-preserved examples of *Qerunia cornuta*, *Pecten* sp., *Pectunculus* sp., *Venus* sp., *Cardita Viquesneli*, *Astarte* sp., *Macrosolen Hollowaysi*, *Lucina* sp., *Natica* sp., *Cerithium* sp., *Clavelithes longævus*, *Voluta* sp., *Dentalium* sp.	1
10.	Hard purplish clays...	7
11.	Soft yellowish sandstone with *Ostrea* sp., *Cardita ægyptiaca*, *Lucina* sp., *Turritella* sp., and sharks' teeth. Upper surface tends to become dark, ferruginous, and concretionary	1
12.	Purple clays, with strings of gypsum	6
13.	Soft light-yellow sandstones with harder shelly bands and occasional concretionary beds, forming vertical cliff-wall...	17
14.	Grey and brown clays.	18
Ravine Beds.	Total	50

In the cliffs west of the end of the lake the upper bed No. 9 continues highly fossiliferous and yields the most perfectly preserved molluscan remains to be found in the Fayûm and probably in Egypt.

A few kilometres east of the end of the lake a band of large globular concretions occurs in the thick brown sandstone forming the vertical face of the cliff. In many places the effect of weathering of these rocks is of some interest, numerous "earth-pillars" having been formed; these are largely the result of the action of blown sand, assisted by rain, the concretions being left capping pillars of brown sandstone, the sides of which are sculptured by the wearing action of sand. The curious perforate or cellular appearance which the weathered surfaces of this sandstone assume after long exposure are particularly noticeable in this neighbourhood and in the Zeuglodon Valley further west.

In the well-marked hill distant 17 kilometres to the north-east of Gar el Gehannem, the soft fossiliferous sandstones of this series are crowded with *Operculina*, *Nummulites*, and many species of mollusca beautifully preserved.

At Gar el Gehannem the series is seen (Fig. 2 and detailed section page 36) forming part of the slope of the hill, underlain by the Ravine beds, and capped by part of the

Qasr el Sagha series. It here consists of yellow sandstones divided by a bed of clay; the sandstones are often crowded with nummulites (of two species); also *Operculina* (*discoidea?*), echinids, *Balanus* sp., *Ostrea Reili*, *O. Fraasi*, *Carolia placunoides*, and species of *Pecten*, *Pinna*, *Cardita*, *Teredo*, *Turritella*, and *Cerithium*.

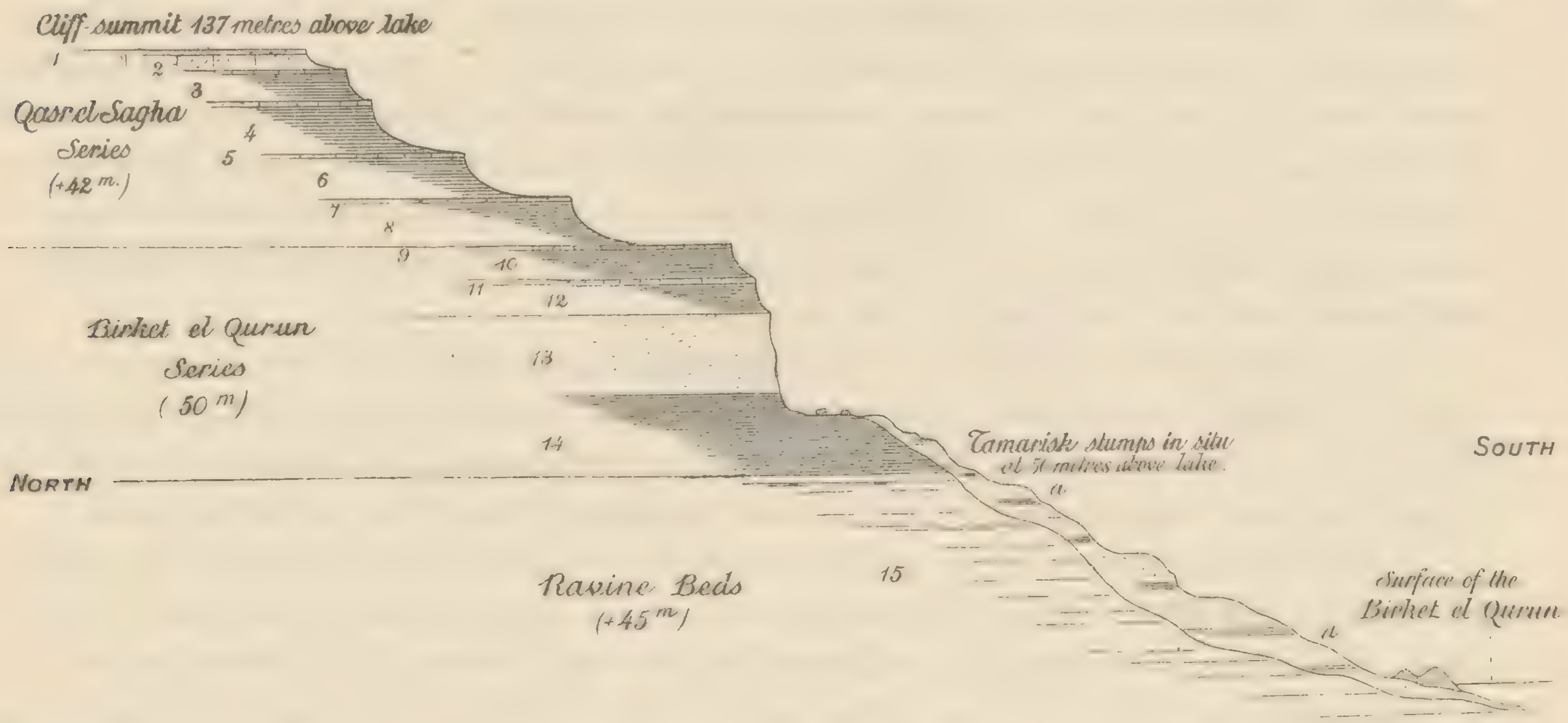


FIG. 5.—Section of cliffs, western end of the Birket el Qurun.

Pleistocene.—(*a*) Lacustrine clays and sands with freshwater shells and fish-remains; *Middle Eocene*, 1. 14 Clays, sandstones and impure limestones; 15 White shaly clays and marly limestones.

In the Zeuglodon Valley, 12 kilometres W.S.W. of Gar el Gehannem, the brown sandstones of the Birket el Qurûn series are divided by a narrow band of fine-bedded grey clay. Most of the fantastically shaped hills on the south-west slope of the valley are carved out of the lower division of the sandstone. The concretionary beds of the Birket el-Qurûn series are not developed in this neighbourhood. Remains of *Zeuglodon* of both species (*Z. Osiris* and *Z. Isis*) are remarkably abundant and the skeletons of these cetaceans may be found in every stage of weathering. The larger species, *Z. Isis*, is the more common, and series of vertebrae, twelve to fifteen in number, can frequently be counted in situ. The remains are most abundant enclosed in the hard brown nodular bands of the series but in such cases it is almost impossible to extract specimens of any value. In one instance an almost complete skull of *Z. Isis*, measuring 116 cm. in length, was found enclosed in a large block of the nodular rock.[1] Bones are frequently to be observed protruding from the wind-worn sides of the small hills, while those portions of the skeleton already weathered out litter the ground below. Exposed they break up with rapidity, although where the enclosing rock is softer than the bone itself, parts of the skeleton beautifully preserved and perfectly free from matrix may sometimes be obtained.

[1] This block was far too large to transport by camel, but it may be feasible to effect its removal to Cairo by cart when opportunity offers.

The molluscan fauna is represented by very large numbers of pseudomorphs in sulphate of strontium (celestine) of the genera *Lucina*, *Turritella*, *Fusus* and *Nautilus*, the profusion of individuals of a species of the latter being very marked. In the case of lamellibranchs the radiating bundles of crystals of celestine are seen to originate from a point placed centrally on one of the valves, so that on this side (of a slightly weathered example) a radiating mass of crystals is seen, while on the other appear numerous contiguous circular areas, representing the terminal ends of the bundles of crystalline fibres or needles. Apart from the quantities of organic pseudomorphs, masses of crystalline celestine occur in the sandstones throughout the valley, and altogether the quantity of sulphate of strontium present must be very great. The gigantic oysters and other fossils which occur in some of the overlying higher beds, and the numerous individuals of nummulites in the sandstone itself, never seem to be replaced by celestine.

Nummulites of two species are very abundant in some bands and the presence in the Zeuglodon Valley of occasional individuals of the large *N. gizehensis* shows that in favourable localities this species persisted throughout the time represented by the deposition of the Ravine beds and ranged upward into the basal members of the Birket el Qurûn series.

In the higher hills within the valley, and in the hill-mass on the south side, the yellow sandstones of the Birket el Qurûn series pass up into the basal members of the Qasr el Sagha series. In their upper limits the sandstones become very nummulitic in places and at the top bands made up of *Carolia* and *Ostrea* occur. Above these, in the basal members of the Qasr el Sagha series, huge oysters and finely preserved specimens of *Qerunia cornuta* are conspicuous.

The dip in the valley is 2° north.

The southern face of the hill-mass lying immediately to the south of the Zeuglodon Valley is an almost sheer cliff of over 100 metres, descending to the silt covered basin below which has already been noticed (page 23). On this escarpment the hard nodular marly limestones of the Ravine beds are seen near the base, overlain by a mass of grey shaly gypseous beds; above, forming as a rule a vertical wall of rock, lies the hard massive brown sandstone of the Birket el Qurûn series, here undivided by clays; at the top, highly fossiliferous alternating clays and limestones are found forming the summit of the hills.

The exact junction between the Birket el Qurûn series and the overlying Qasr el Sagha beds is naturally perfectly arbitrary, many of the fossils being common to both groups. *Carolia placunoides*, which is perhaps the most abundant fossil in the Qasr el Sagha series, is sometimes very common in the upper beds of the underlying group, and, as shown before, is common enough in the still lower *Nummulites gizehensis* beds of Wadi Rayan. So that, though this fossil itself is no criterion, its relative abundance in the upper series justifies those beds being called the "Carolia beds," the additional name of the Qasr el Sagha series being taken from the old ruin of that name where these beds are fully seen.

MIDDLE EOCENE ESCARPMENT (QASR EL SAGHA SERIES) 12 KILOM. WEST OF QASR EL SAGHA.

D.—Qasr el Sagha Series *(Carolia Beds)*.

This division is strikingly developed in the north of the Fayûm, where it forms a bold escarpment of great length, consisting of an alternating series of very fossiliferous clays and limestones, with sands and sandstone in the upper beds, of a total thickness of 175 metres.

This series is the equivalent of the well known Upper Mokattam beds of Jebel Mokattam, immediately to the east of Cairo. The cliffs of this hill are among the best known in Egypt and have been studied by many geologists, including Zittel, Schweinfurth, Mayer-Eymar, etc.; these authors have classified the whole of the Upper Mokattam of Cairo as equivalent to the Upper Parisian (Middle Eocene) of Western Europe. The series is far better developed in the Fayûm than at Jebel Mokattam, where the total thickness is only some 70 to 80 metres.

In consequence of the discovery in these beds of a highly interesting vertebrate fauna, including land animals, the series becomes of the greatest importance. As already mentioned, as long ago as 1879, Schweinfurth, during a journey across the Fayûm, obtained remains of *Zeuglodon* in the underlying series from the island in the Birket el Qurûn. Subsequently[1] he obtained additional remains of the same cetacean in a violet marl belonging to the present series, from a locality $12\frac{1}{2}$ kilometres west of Qasr el Sagha[2]; these remains, as already mentioned, were described by Dames as *Z. Osiris*. Since then important finds of land and marine mammals and reptiles have been made in different beds of this series; these will be referred to later.

The outcrop of the Qasr el Sagha series occupies a large part of the northern desert of the Fayûm. The beds are, however, best seen in the cliffs about 8 kilometres north of the Birket el Qurûn, where they form a steep double escarpment, running east and west, nearly parallel to the northern shore of the lake. The dip of the series being northward at a very low angle, and the upward slope of the ground being in the same direction, this cliff dies out a few kilometres north-east of Qasr el Sagha. A little further north, however, a N.W.–S.E. fold and fault again exposes nearly the whole of the beds of the series, forming prominent cliffs as before.

In the conspicuous hill $17\frac{1}{2}$ kilometres 28° N. of E. (magnetic) of Tamia the series consists of innumerable alternations of clays and sandy limestone. The calcareous beds nearly always contain numerous examples of *Carolia placunoides*, *Ostrea* and *Turritella* of several species, but other well-preserved fossils are rare. The exposed beds here have a thickness of about 55 metres, and are underlain by the Birket el Qurûn beds with a well-marked band of concretionary sandstone, the thickness of the two series together being 127 metres. The upper beds of the former series are not here exposed, the top of the hill being

[1] SCHWEINFURTH, op. cit. p. 139.

[2] A ruin discovered by Schweinfurth in 1886 and hence often spoken of as "Schweinfurth's Temple." Nothing certain is known as to its age or former use, but we may infer from its situation just beyond the limits of the high-level lacustrine clays, that it was built and inhabited only while Lake Mœris stood at its highest level.

formed of well-rounded flint and quartz pebbles embedded in a base of finely crystalline gypsum (2 metres thick), a deposit of Pleistocene times.

To the north of Tamia a large area of desert is occupied by the beds of this series; the district has the character of an undulating plain with occasional groups of hills and low irregular escarpments. At the groups of hills 12 kilometres N.N.E. of Tamia, and just to the east of Garat el Faras, the Qasr el Sagha beds are found to consist as usual of an alternating series of sands, sandstones, clays, marls and limestones, with numerous individuals of *Ostrea*, *Carolia* and *Turritella*, besides vertebræ, teeth and spines of large fish.

We may pass now to the locality where this series shows its best development and exposure, the beds being all concentrated in one bold escarpment, generally divisible into an upper and a lower cliff. These cliffs overlook the Birket el Qurûn, although distant usually about 8 kilometres, being separated from the lower escarpment of the Birket el Qurûn series (immediately above the lake shore) by a broad plain, the surface of which is usually the dip-slope of a hard bed of sandstone. From Qasr el Sagha ($6\frac{1}{2}$ kilometres N.N.E. of Dimê) these cliffs trend westward, keeping approximately the same distance from the north shore of the lake; they have been followed and mapped for a distance of 70 kilometres to a point 13 kilometres N.N.W. of Gar el Gehannem, whence they could be seen still trending in a direction slightly south of west (see Plate XVII).

Small faults are of frequent occurrence along these escarpments, but are not of other than local interest; they almost invariably have their downthrow to the north, and it seldom exceeds a few metres. Fig. 5 shows a section through one of these faults near Qasr el Sagha.

The following detailed section (Plate XXIII) will show the character of the beds forming this division. As might be expected in such a series, although the calcareous bands are fairly constant, there is a continuous change of character among the sandy and clayey sediments from point to point; the false-bedding is in places very striking.

The main part of the section was measured $3\frac{1}{2}$ kilometres north-east of Qasr el Sagha, but the lower beds not being exposed at that point, they were added from the cliffs at the ruin itself. The total thickness is 154 metres.

Top.	Thickness in metres.
1. Hard, white, grey-weathering, sandy limestone with numerous shell-casts: *Echinolampas Crameri*, Loriol, *Plicatula Bellardi*, May.-Eym … … … … … … …	2
2. False-bedded sand and sand-rock with grey and green clays; concretions and bands of ironstone.	
Hard, dark-brown or purplish ferruginous sandstone band. Occasional vertebrae of *Zeuglodon Osiris*, Dames, *Pterosphenus* (*Mœriophis*) *Schweinfurthi*, Andr., crocodilian and fish-remains; coprolites … … … … … … … … … … … … … …	16
3. Hard, calcareous, ferruginous, clayey sandstone with brown ironstone concretions. Occasional fish-spines.	
Clays with massive veins of gypsum forming a stock-work, and left weathered out above surface. *Cardium Schweinfurthi*, May.-Eym., *Cardita fajumensis*, Oppenh., (*Cossmannella ægyptiaca*, May.-Eym[1]), *Crassatellithes* sp.… … … … … … …	9
4. Hard, yellow, gypseous sandy limestone or calcareous sandstone…… … … … …	$1\frac{1}{2}$
5. Sandy, glauconitic clays with gypsum; oyster-bed at base in places. *Alectryonia Clot-Beyi*, Bellardi, *Exogyra Fraasi*, May.-Eym … … … … … … … …	10

[1] See OPPENHEIM, op. cit. p. 105.

2nd escarpment.

6.	Hard or friable limestone, sometimes sandy, full of *Carolia placunoides*, Cantr., and *Exogyra Fraasi*, also *Ostrea* aff. *heteroclyta*, Defr., *Ostrea Reili*, Fraas., *O. elegans*, Desh., *Plicatula Bellardi*, May.-Eym., *Pectunculus (?) ægyptiacus*, Oppenh. *Qerunia (Hydractinia) cornuta*, May.-Eym.	2
7.	Purplish clays interbedded and remarkably current-bedded with ash-grey sands, with both ferruginous and highly carbonaceous bands with plant-remains, lignite and natural charcoal. Vertebrate remains fairly common, the mammalian including *Zeuglodon Osiris*, *Eosiren libyca*, Andr., *Mœritherium Lyonsi*, *Barytherium?* Andr.; the reptilian *Stereogenys Cromeri*, Andr., and *Tomistoma africanum*, Andr., with numerous coprolites; also frequent remains of siluroid and other fish. Masses of coral, *Astrohelia similis*, Felix, in places	12
8.	Hard grey, close-grained, concretionary sandstone, frequently weathering into huge elongated rounded masses ; *Turritella pharaonica*, Cossm.	
	Hard, purplish clays with grey sandy clays, sandrock, etc. Occasional crocodile and fish-remains......	4
9.	Hard ripple-marked sandstone. False-bedded sandstones with clay partings ; ferruginous and lignitic bands with lumps of lignite. Occasionally coprolites and remains of Sirenia and Crocodilia are numerous	7
10.	Hard or friable brown sandy limestone with shell-casts filled with scalenohedra of calcite. *Carolia placunoides*, *Turritella* sp...	½
11.	Gypseous clays, with red ferruginous band ; weathering to paper-shales below... ...	1½
12.	Light-yellow limestone and calcareous sandstone with sharks' teeth, *Mesalia fasciata*, Lam., *Cassidaria* sp., *Rimella rimosa*, Sol., *Trachelochetus bituberculatus*, Cossm., *Turritella carinifera*, Desh., *T. Lessepsi*, May.-Eym., *Cardita fajumensis*, Oppenh. *Goniopora?*	1
13.	Slate-blue and brown gypseous clays with band containing *Mesalia* sp., *Cassidaria nilotica*, Bell., *Exogyra Fraasi* and *Goniaræa elegans*.	3
14.	Sandstone and sandrock, light yellow...	1
15.	Yellow sandy friable limestone with casts of shells and *Mesalia fasciata*, *M. oxycrepis*, May.-Eym., *Turritella Lessepsi*, *T. pharaonica*, Cossm., *Alectryonia Clot-Beyi*, *Ostrea Reili*.	½
16-17.	Sands, sandy clays and clays with a double band of limestone containing *Ampullina hybrida*, Lam., *Melongena nilotica*, var. *bicarinata*, May.-Eym., *Tudicla* aff. *umbilicaris*, May.-Eym., *Turritella Lessepsi*, *T. parisiana*, May.-Eym., *Solarium* sp., *Alectryonia Clot-Beyi*, *Plicatula polymorpha* (occasional), *Lucina fortisiana*, Defr., *L. pharaonis*, Bell., *Mytilus affinis?* J. and C. Sowerby, *Astrohelia similis*, *Goniaræa elegans*, Mich.; numerous vertebrate remains both above and between limestones including *Zeuglodon Osiris*, *Eosiren libyca*, *Barytherium grave*, Andr., *Moeritherium Lyonsi*, *M. gracile*, Andr., *Gigantophis Garstini*, Andr., *Pterosphenus Schweinfurthi* and *Tomistoma africanum*, Andr. The remains of a siluroid fish are abundant; also *Propristis Schweinfurthi*, Dames. Large numbers of coprolites. Silicified wood. ...	12
18.	Brown sandy limestone with casts of shells, *Akera* aff. *striatella*, Lam., *Ampullaria*, n. sp., *Gisortia gigantea*, Munst., *Lanistes antiquus*, Blanck., *Melongena nilotica*, var. *bicarinata*, *Mesalia* sp., *Cassidaria nilotica*, *C.* aff. *nodosa*, *Solarium* aff. *bistriatum*, Desh., *Alectryonia Clot-Beyi*, *Cardium Schweinfurthi*, *Exogyra Fraasi*, *Lucina pharaonis*, Bell., *Macrosolen Hollowaysi*, J. Sowerby, *Meretrix nitidula*, Lam., *M. parisiensis*, Desh., *Ostrea flabellula*, Lam., *Tellina* sp., overlying clays with gypsum.	4
19.	Sandy limestone with numerous *Carolia placunoides* and *Turritella imbricataria*, Lam.	1
20.	Greyish-blue and brown ferruginous, sandy, and other clays. Plant remains	13
21.	Friable shelly limestone with occasional small calcite veins	½
22.	Clays	4

23. Hard yellow sandy limestone with *Ostrea* and *Anisaster (Agassizia) gibberulus* ...	½
24. Clays with thin bands of fibrous gypsum	6
25. Hard friable shelly limestone with numerous fossils, including *Dictyopleurus Haimi*, Dunc. and Slad.; *Akera* aff. *striatella*, *Turritella carinifera*, *T. imbricataria*, *T. pharaonica*, *Alectryonia Clot-Beyi*, *Arca tethyis*, Oppenh., *Cardita* aff. *carinata*, J. Sowerby, *C.* aff. *depressa*, Locard., *C.* aff. *triparticostata*, Cossm., *C.* cf. *gracilis* and *depressa*, Locard., *Cardita fajumensis*, *Cucullœa* aff. *crassatina*, Lam., *Exogyra Fraasi*, *Glycimeris (Pectunculus) pulvinatus*, Lam., *Ostrea* aff. *Reili*, *Spondylus œgyptiacus*, Bull. Newt., *Pecten solariolum*, May.-Eym., *P. moelehensis*, May.-Eym., *Qerunia cornuta*, *Euspatangus cairensis*, Loriol, *Linthia* sp., *Anisaster gibberulus*, *Schizaster* aff. *africanus*, Loriol; bryozoa...	½
26. Sandy clays with gypsum	7
27. Friable, gypseous, impure limestone with *Exogyra Fraasi*, *Carolia placunoides*, *Turritella* sp., *Qerunia cornuta*, *Alectryonia Clot-Beyi*...	½
28. Sandy gypseous clays	3
29. Friable sandy limestone with *Carolia placunoides*, *Exogyra Fraasi*, *Turritella* sp. (The ruin of Qasr el Sagha is built on this bed)	1
30. Gypseous sandy clays with occasional oyster-limestone with *Qerunia cornuta;* ferruginous sandstone band, etc...	27
Total...	154

Hard grey sandstone with *Zeuglodon* and numerous *Carolia*, *Ostrea*, etc., in places, capping plain to south of Qasr el Sagha and forming the top of the "Birket el Qurun series."

The chief divisions of the series remain fairly constant and can be recognized and followed for many kilometres westwards.[1] The lower beds form the summits of Gar el Gehannem and the neighbouring hills (see Fig. 2 and section p. 36), the upper beds of the series being exposed in the higher escarpments to the north.

Although vertebrate remains are more common on some horizons[2] than on others, they are occasionally met with in most of the beds. The most prolific bone horizon is, however, about half-way down, i.e., those beds numbered 16 and 17 in the above section; bed 7 also yielded a number of remains. At the point where the upper part of the section was measured, 3½ kilometres north-east of Qasr el Sagha, the beds 16 and 17 yielded a considerable number of land-animal remains, all of which occurred within a fairly confined space, suggesting that they had been carried out from the land to this point by a strong river-current and deposited when the latter became too feeble to carry them further out to sea. The same beds were also examined in the faulted bay 8 kilometres to the north, but no bones, or at most a very occasional fragment or two, were obtained here. This is easily explained by the greater distance of this locality from the land-mass to the south. Westwards the same beds were always found more or less bone-bearing, isolated detached mandibles, limb-bones and vertebræ of *Mœritherium*, being of frequent occurrence, although no such complete remains were found as those from near Qasr el Sagha. Reptilian and fish

[1] Details of a section of the lower beds of this group near the end of the lake have already been given on p. 44.

[2] As might be expected, vertebrate remains occur chiefly in the sandy and clayey beds. Skeletons of marine animals such as *Zeuglodon* and *Eosiren* may, however, be frequently observed embedded in the hard intercalated limestones. Limestone cranial-casts of these animals are thus sometimes found, and one of these has already been figured and described (Elliot Smith, *The Brain of the Archæoceti*, Proceedings Royal Society, Vol. 71, pp. 322-331. Some most beautifully formed casts from one of the limestone beds were eventually determined by Andrews to be casts of the air passages of crocodile skulls.

UPPER BEDS OF FLUVIO-MARINE SERIES WITH BASALT CAP, LOOKING WEST FROM THE EASTERN EXTREMITY OF JEBEL EL QATRANI.

bones are very widespread throughout the area. An extensive and detailed examination of these beds over a large area can hardly fail to yield important results, as other localities where skeleton-carrying currents came out from the land would very likely be discovered.

That the Qasr el Sagha series was deposited in fairly shallow water at no great distance from land seems certain, not only from the general lithological character of the beds but from the number of land-animal remains and the frequency of river and shore-frequenting whales, dugongs, crocodiles and turtles. The clays, moreover, are found to abound with impressions of plants, and in some cases are highly lignitic, being made up of compressed masses of vegetation including solid twigs, now found in a state more resembling charcoal than ordinary dense lignites; some bands approximate to an impure brown coal. In certain beds of the series further to the west, very thin seams of true coal occur; they were, however, never seen to exceed one or two millimetres. The intercalated bands of limestone are generally impure and do not indicate any great conditions of depth, but only rather a temporary cessation in the supply of sand and clay. Corals, moreover, abound along many horizons.

Section XI.—UPPER EOCENE (BARTONIAN)—LOWER OLIGOCENE.

E.—**Fluvio-Marine Series** *(Jebel el Qatrani Beds).*

Throughout the north of the Fayûm depression the Qasr el Sagha beds, forming the uppermost Middle Eocene, are followed by an unique series[1] of variegated[2] sands and sandstones, with alternating beds of clay and clayey marl. The ever-recurring bands of limestone, so common to the underlying marine beds, have now almost completely disappeared, being represented by only an occasional bed of calcareous grit, marl, or thin band of limestone. In the upper part of the series occurs a horizontal sheet of basalt,[3] in all probability contemporaneously interbedded; this forms a convenient datum line and may perhaps be provisionally taken as an arbitrary junction between the Eocene and Oligocene. Although as a rule remarkably barren of organic remains, certain bands, especially in the upper part, yield numerous individuals of a few species of mollusca, including *Lucina*, *Arca*, *Mutela*, *Spatha*, *Unio*, *Lanistes*, *Turritella*, *Melania*, *Potamides*, *Cerithium* and *Pleurotoma*. From such an assemblage we may without doubt conclude that the conditions under which the series was deposited were estuarine or fluvio-marine, and this is further proved by the non-marine lithological character of the beds. The enormous quantities of silicified wood which occur in certain beds, in the shape of hundreds of trees of great length and girth, together with the numerous remains of land-animals, crocodiles, tortoises and turtles, indicate that rivers of considerable size emerged from the land to the south, the coast-line of which was probably

[1] Schweinfurth appears to have been the first to examine these beds.

[2] One would imagine that there must have been a considerable amount of ferruginous matter in the water at the time of deposition of the Fluvio-marine series, the prevailing colours of the deposits being red and yellow.

[3] Mayer-Eymar appears to believe the depression of the Fayum is the result of the volcanic activity which produced these basalt flows. He says (op. cit. *Nouvelles recherches, etc.*, p. 218.) "Or, de cette extension extraordinaire du phénomène volcanique dans l'ouest du grand désert, il est, en premier lieu, permis de conclure que c'est par suite de son action excavante qu'a eu lieu l'effondrement rempli de nos jours, en partie par le lac de Fayum."

Personally, we cannot see the slightest evidence in support of this. Where the basalt occurs as a hard band it usually causes steep cliffs as at Widan el Faras, owing to its protecting the underlying beds from denudation. To the west, in Jebel el Qatrani, its thickness and hardness determine the character and steepness of the escarpment below.

not far distant. In fact the retreat of the sea, which as already mentioned, had probably already begun in Middle Eocene times, was now still further continued, although the cause of this was apparently not so much due to elevation of the land as to the continued deposition of sediment from south to north beyond the land-shore. We may in fact regard the series as a huge delta deposit in an area of local depression, in which the great accumulation of sediment brought down from the land continually caused the gradual retreat of the sea to the north.

The same conditions would even appear to have continued on to Pliocene times, as from the Fayûm northwards stretches an immense plain of lithologically similar rocks, evidently accumulated under similar conditions, and which appear to contain newer and newer faunas from south to north. Thus, while in the Fayûm the remains are of Middle and Upper Eocene and Lower Oligocene age, when the latitude of Mogara is reached, some 70 kilometres further north, a fauna distinctly Lower Miocene in aspect occurs; further north again, as at Wadi Natrûn, Pliocene remains are abundant. We may hope therefore that this otherwise barren desert, when carefully and systematically explored, will yield us a continuous record of the vertebrate life of the northern part of the African continent from Eocene to Pleistocene times.

In the Fayûm, over a length of 80 to 90 kilometres, the basal beds of the Fluvio-marine series, at a height of only a few metres above the top of the Qasr el Sagha series, are frequently found to contain the remains of land-animals,often in sufficient quantities to form in places a true "bone-bed." Besides land-mammals, remains of large tortoises, turtles and crocodiles, are very common, some of the latter being identical with those of the Qasr el Sagha series below. Chelonian and crocodilian remains are to be found on various horizons, but so far none but fragmentary mammal remains have been observed in the higher parts of the series. It is interesting to note that the bones in these beds appear to be most common near the accumulations of fossil trees, thus suggesting that they were floated out from the land at the same time and by the same river-currents. The porous character of the sands and sandstones of this group has resulted in the remains not being in nearly so hard or durable a condition, except when coated with ferruginous sand, as those in the series below, although the actual state of preservation is even more perfect.

Analysis shows that these bones, with the exception of the loss of all organic matter, have undergone very little change. A sample examined by Mr. Lucas was taken from a typically preserved pelvis of *Arsinoitherium* and gave the following result :—

Determined.		Calculated.	
Silica	0·57	Silica	0·57
Oxide of Iron	1·98	Oxide of Iron	1·98
Lime	51·40	Calcium Phosphate	76·11
Magnesia	trace	Magnesium Phosphate	trace
Phosphoric Acid	34·86	Calcium Sulphate	4·64
Sulphuric Acid	2·74	Calcium Carbonate	14·75
Loss on ignition, being Carbon dioxide	6·13	Organic Matter	nil
Chlorine	trace	Sodium Chloride	trace
Not determined	2·32	Not determined	1·95
	100·00		100·00

The following composition of the bones of an ox, from an analysis by Berzelius, is appended for comparison:—

	%
Phosphate and Fluoride of Calcium	57·35
Carbonate of Calcium	3·85
Phosphate of Magnesium	2·05
Soda and a little Sodium Chloride...	3·45
Organic Matter...	33·30
	100·00

It is curious that these Eocene bones should have so completely preserved their original composition considering the almost universal silicification of the trees deposited in the same beds.

Most frequently the vertebrate remains are found in an unconsolidated false-bedded clean quartz sand, the grains of which are semi-rounded or angular; in some layers the sand is very coarse and polished, and mixed with fine gravel. These deposits of sand, apparently brought down by river floods, are not continuous along any particular horizon, but are intercalated here and there in the ordinary sandstones, clays and marls of the series; they occur chiefly, however, as local lenticular masses along a more or less constant horizon near the base of the series. The bone-remains are not absolutely confined to these deposits of river-sand, but like the silicified trees are far more common in them than elsewhere. Scattered mammal bones occur in the lower clays, marls, and hard concretionary sandstones, while the remains of aquatic animals, such as turtles and crocodiles, may be found almost anywhere.

From an examination of the series in the field, there is no doubt that, in at least the centre of the area, the deposition of the lowest beds was continuous with those of the Qasr el Sagha (Middle Eocene) series below. Followed away from the centre (i.e. the district round Widan el Faras, the eastern extremity of Jebel el Qatrani) the series gradually thins out, and eastwards, at Elwat Hialla, some 23 kilometres north of Tamia, has a thickness of only 40 metres, the basal beds being apparently laid on to a bed of limestone of the Qasr el Sagha series about the horizon of Bed 12 in Section XXIII. The junction here is apparently one of perfect conformity as far as the individual beds go, and the peculiar sequence does not seem to be due to ordinary overlap; it appears as if the change from marine to estuarine conditions had set in earlier here than further to the west, with the result that the upper Qasr el Sagha beds are wanting. Moreover, the accumulation of estuarine beds went on so slowly in this locality that the series does not attain to nearly its normal thickness, while further east it dies out altogether. The slight dip to the north is identical in both series, their lithological characters being, however, very different.

Although the Qasr el Sagha series contains numerous bands of clay and sandstone, the continual recurrence of thick beds of limestone at once gives it a distinguishing feature from the group under discussion; the latter is in fact characterized by the highly-coloured sandy, and to less extent clayey, character of its beds. While the Middle Eocene is essentially marine, the succeeding formation marks the retreat of the sea and the incoming of estuarine and brackish water conditions.

Before discussing the age of the Fluvio-marine series it will be well to describe its development in the field. The beds of the complex are throughout the district always found following on above the Qasr el Sagha beds, although their thickness varies considerably, as might be expected in a series of this nature. The most easterly locality to which the formation was mapped is the scarp 23 kilometres due north of Tamia, known as Elwat Hialla. Here the beds form a separate escarpment, consisting of only about 40 metres of sands and sandstone grit (sometimes silicified) with pieces of silicified wood: some of the beds of sandstone have a concretionary stem-like weathering. From this point these beds extend westwards far beyond the western end of the lake, always forming the highest escarpments of the Fayûm depression. A kilometre or two from our most easterly point the first basalt sheets are seen, and these, preserving the same level as far as can be observed, continue some 60 kilometres further west, to a point nearly due north of the western end of the Birket el Qurûn. The series, only 40 metres thick at the eastern end, gradually thickens as it is followed westward, until it reaches its maximum development in the cliffs of Jebel el Qatrani, north-west of the temple of Qasr el Sagha, where a thickness of some 210 metres is attained.

Just 29 kilometres N.N.E. of Tamia (6 kilometres N.W. of the prominent western scarp of Elwat Hialla), a long hill offers a good section of these beds, which consist of a variegated group of green sands, red clays, coarse sandstones, red and yellow sand and sandstone, etc., capped by a band of hard impure yellowish limestone with numerous enclosed sand-grains (calcareous grit). Near the same place is an interbedded sheet of basalt, which is sometimes followed by another band of impure limestone and the latter by false-bedded sandstone. Huge logs of weathered-out silicified trees are seen strewn about.

The following is a detailed section of the series, measured from a point $3\frac{1}{2}$ kilometres W.N.W. of Elwat Hialla, and about 28 kilometres N.N.W. of Tamia, to the top of the escarpment 4 kilometres further north:—

Undulating sandy, gravel-covered desert[1] stretching northwards.

Top of escarpment.	Metres.
1. False-bedded sandstones...	
2. Band of impure limestone	8
3. Interbedded basalt sheet...	
4. Sandstone ...	
(Section continued in hill ¾ kilometre further north-east).	
5. Hard yellow limestone with enclosed sand-grains; cavities full of calcite...	1
6. Greenish-white sand-rock	1
7. Hard reddish-brown stem-weathering sandstone	$1\frac{1}{2}$
8. Greenish or white sand and sand-rock...	3
9. Variegated sandy clays; sand-rock with occasional fragments of bone	6
10. White sand-rock	1

[1] Pebble bands are occasionally met with in the coarser sandstones of the Fluvio-marine series, and it would seem that from them are derived the pebbles of quartz and flint which so invariably strew the desert-surface to the north to beyond the latitude of Cairo. Those flints on the surface are largely broken up and flaked by changes of temperature, but show comparatively little shaping by blown sand; the white quartz pebbles on the other hand, while seldom or never broken or flaked, are invariably more or less facetted, frequently into typical "dreikanter" or pyramid-pebbles; below the surface both varieties are perfectly water-rounded.

EL QATRANI RANGE FROM THE SOUTH-EAST.

11. Rose-coloured sandstone...	2
12. Hard grey white marly clays...	2½
13. Coarse yellow sandstone...	5
14. Reddish, white, and variegated sands and sand-rock	8
15. Grey, reddish and yellowish clays, with bands full of plant-remains	3½
16. Brown clayey sandstone...	2
17. Greenish sandstone	1
18. Sandy grey clay	1½
19. Hard grey sandstone	½
20. Greenish sand-rock and clayey sandstone	3
21. Dark red clay	1
22. Sands, etc.; outcrop of bed covered with silicified trees of large dimensions, 12–15 metres long	10
23. Clays with hard grey false-bedded sandstone and showing fine mammilary weathering at top. Silicified logs on surface	8
24. Red clays, sandy clays and argillaceous sands	4
25. Reddish sand-rock	1
26. Yellowish sand-rock, in part false-bedded	2
27. Red clays with thin sandy bands	1½
28. Coarse grey sandstone	2
29. Red and green sandy clays with thin band of hard white sandstone at top	1
30. Bright red clay...	4
31. Red clays with thin green sandy bands	3
32. Greenish sand-rock with thin red clayey bands...	1
33. Reddish white mottled clayey sandstones passing up into red and white mottled clays and sandy clays	8
34. Fine white sand... 35. Black ferruginous silicified sandstone...	3
Total thickness...	90

Base.

Junction with Middle Eocene (Qasr el Sagha series).

A little further west, at a point 25 kilometres north of the eastern end of the Birket el Qurûn, thick beds of white coarse sandstone form the upper part of the escarpment. Below comes a bed of yellowish impure limestone and below this an interbedded sheet of basalt 21 metres thick, underlaid by more white sandstone.

The series has almost always a constant dip of two or three degrees to the north. Silicified trees are very commonly found strewn over the surface both near the base and high up in the series.

At a point about 14 kilometres north of Qasr el Sagha definite organic remains other than bone-fragments were for the first time met with in the series. Here a fragment of ochreous-coloured grit containing numerous specimens of a small *Melania* was picked up and similar rocks were afterwards found *in situ*. Calcareous grits and impure limestones occurred at the same spot, and one of the harder more compact bands of limestone was found to contain casts of *Cerithium*.

Also at a point 9 kilometres north of Qasr el Sagha hard grey limestones, generally compact and cherty, and sometimes semi-crystalline, are present, containing casts of *Melania*,

frequently filled with calcite. These overlie variegated sandstones, and occur at about 40 metres below the basalt near the top of the escarpment.

Blanckenhorn has determined my fossils from these localities as follows:—

Melania nov. sp., allied to *M. Nysti* of the Oligocene.

Potamides scalaroides, Desh., an important guiding form of the Middle Beauchamp Sands of the Paris Basin, and thus Upper Eocene.

Potamides tristiatus, Lam., of the Parisian (*Cerithium crispum*, Desh.,) is nearly related to the frequent Middle and Upper Eocene *C. perditum*, Bay, between which, according to Cossmann, transitions exist.

Cerithium tiarella, Desh., of the Middle and Upper Eocene, but more especially in the latter.

Blanckenhorn considers these determinations as certain, and thus marking the complex as Upper Eocene, on the level of the "Beauchamp Sands" of the Paris Basin, and consequently of the Lower Headon Hill beds and Barton Clay of the South of England.

The following section was measured from the base of the series, 2½ kilometres N.N.W. of Qasr el Sagha, to the summit of the escarpments, 2 kilometres N.N.W. of Widan el Faras. The series has its maximum thickness at this point.

Summit of escarpment of Fayûm depression, 2 kilometres N.N.W. of Widan el Faras.

Top.		Metres.
1.	Sandstones with band of coarse dark ferruginous grit; silicified logs occur weathered-out of this bed...	18
2. 3.	Coarse sandstone-grit with yellowish calcareous base. Greyish clay, possibly a product of decomposed basalt	1
4.	Basalt sheet, soft friable, grey or bright green, and decomposed at base.	5
5.	Hard yellow calcareous-grit with calcite-filled cavities, passing into semi-compacted yellowish sand, hardened at junction with basalt	1
6. 7.	White and red sands.. Greenish sandstones and yellow concretionary sands with 2·5 cm. layer of calcareous grit, with gastropods including large *Cerithium*, *Melania* sp., *Turritella pharaonica*, *Pleurotoma ingens*, May.-Eym., occasional lamellibranchs and also *Callianassa*.	27
8.	White, green and brown sands and sand-rock	17
9. 10.	Hard yellow calcareous grit ... Red and white clayey sand and sandy clays; some pebbly bands; *Lucina* sp., *Unio* sp.,[1] preserved in brown ironstone, common in places on this horizon...	10
11. 12. 13.	Coarse grey and white sand (2 metres)... Red clayey sands (1 metre) White and yellow sand and sand-rock...	5
14.	Red clays	7
15.	Sandy ferruginous band with lamellibranchs and gastropods of genera *Unio*, *Pseudodon*, *Mutela*, *Spatha* and *Lanistes*, indicating fluviatile or fresh water conditions of deposition	5

[1] Many of the fossils mentioned in this profile were only discovered after long search, and had to be inserted in the measured section afterwards. Their position therefore is only approximate, as individual beds could not always be correlated at the different points where fossils were collected

16. Green clay (1 metre) passing into a red variety	
17. White sandy clay (2 metres)	
18. Red clays	6
19. White, brown, and red sands, partly consolidated	
20. Bright red clay	
21. Hard coarse sandstone	3
22. Hard compact light yellow limestone enclosing sand-grains (½ metre)	
23. White and yellow sands	
24. Greenish clays (1 metre)	5
25. Coarse white sands with *Unio* and *Cardium*-like lamellibranchs preserved in brown ironstone	
26. Grey clay	2
27. Hard yellow impure limestone (forms a small platform)	2
28. Grey clays	
29. Red and yellow sands with hard base of grey sandstone	15
30. Grey sandstones. Base of basalt-capped escarpment.	7
(Section continued ¾ kilometre south-east).	
31. Hard blue-grey compact cherty limestone (½ metre) with casts of *Melania;* hollows often filled with calcite.	18
32. Variegated (red, white and yellow) sands, sand-rock and sandy clays	
33. Hard compact close-grained limestone	18
34. Red and white variegated sands and sand-rock, with some bands of red clay	
35. Hard yellow impure limestone (⅓).	
36. Grey clays	14
37. Coarse white sand	
38. Brown calcareous sandstones	
39. Greenish and grey sandy clays (3 metres)	8
40. Alternating white and red sands	
41. Coarse yellow calcareous grit (½ metre)	
42. Light green sandstone	2
43. Reddish clays	
44. White sand	2
45. Alternating white and bright red sands.	19
46. Grey sandstone with silicified wood; occasional crocodilian and other bones.	
47. Hard red clays	5
48. Grey and brown clays, sandy clays, and thin beds of sandstone with some silicified wood.	19
49. Grey sandstones and loose false-bedded sandy clays with many silicified trees and remains[1] of *Arsinoitherium Zitteli*, Bead., *Palæomastodon Beadnelli*, Andr., *Mæritherium* sp., *Phiomia serridens*, Andr. and Beadn., *Saghatherium antiquum*, Andr. and Beadn., *S. minus*, Andr. and Beadn., *Megalohyrax eocænus,* Andr., *Ancodus Gorringei*, Andr. and Beadn., *Pterodon africanus*, Andr., *Crocodilus* sp., *Tomistoma africanum*, Andr., and large and numerous tortoises (*Testudo Ammon*, Andr.)[2] and turtles[3], and very rarely fragmentary fish-remains.	5

[1] It is not intended to convey the impression that remains of all these vertebrates were found at the point where the actual line of section runs. As a matter of fact at that particular point only *Palæomastodon* remains were observed, while most of the others were obtained some distance further west. Remains of *Mæritherium*, probably identical with *M. Lyonsi*, of the Qasr el Sagha series, in the shape of a beautifully-preserved and almost complete skull, associated with *Palæomastodon* and *Arsinoitherium* in these same beds, I only discovered in January 1903, at a point nearly due north of the western end of the Birket el Qurûn. A preliminary description of this skull has been published by Andrews. *Further Notes on the Mammals of the Eocene of Egypt;* Geol. Mag. Dec. V. Vol. I. N° III, March 1904, pp. 109-115.

[2] ANDREWS and BEADNELL, *A preliminary notice of a Land Tortoise from the Upper Eocene of the Fayûm, Egypt*, P. W. M. report, Cairo, 1903.

[3] In addition to those described from the Survey and British Museum collections, some additional species are described by von Reinach from von Stromer's collection: *Schildkrötenreste aus dem ägyptischen Tertiär;* Sonderabdruck aus den Abhandlungen der Sendeenbergischen naturforschenden Gesellschaft, Band XXIX, Heft I. Frankfurt 1903.

50. Thin bands of limestone	25
51. Yellow sand-rock	
52. Grey sandstone with fragments of bone ($\frac{1}{2}$ metre)	
53. Brown calcareous-grit ($\frac{1}{2}$ metre)	
54. Light green sand-rock and sandstone	
Approximate total thickness in metres...	271

The specimens collected from Bed 15, on about the same horizon as the fossils mentioned from the locality 14 kilometres north of Qasr el Sagha, were examined by Blanckenhorn, who has published the following notice of them:—

"I should first mention the fresh-water shells found by Beadnell in brown sandstone 1 kilometre north of Camp 19 (i.e. at Widan el Faras), which, in the absence of special literature on the Palaeogene fresh-water shells of North Africa and nearer Asia, I have compared with the fauna of to-day, in which I was most kindly helped by Professor v. Martens, Director of the Conchological Collection of the Natural History Museum. The greater number of the forms have a distinctly tropical, and more especially Central African, character.

Unio sp., small, related to the recent *U. Nyassænsis* of Lake Nyassa.

Unio, related to *U. Homsensis*[1] Lea, from Syria, and *U. Bonneaudi* from Cochin China. with many radial folds behind the umbo which run obliquely from the blunt edge backwards towards the hinge-border.

Unio, related to *U. teretiusculus*, Phil. (*Caillaudi*, Fer., *lithophagus*, Ziegli.) of the Nile.

Pseudodon? sp.

Mutela (a genus of tropical Africa) sp., long, with a straight finely-toothed hinge-border which very much recalls that of *Barbatia* (a sub-genus of *Arca*).

Spatha sp. related to *S. dahomeyensis* and *S. Droueti* of Assinia in West Africa.

Lanistes carinatus,[2] scarcely distinguishable from the Nile form.

The *Melania* occurring in mass in the uppermost calcareous bed appears to be a new species[3] whose nearest relation must in any case be *M. Nysti* of the Oligocene, not *M. muricata* of the Eocene, amongst forms at present known.

Turritella angulata, Sow. A marine form, occurring below the basalt and indubitably this species, as it is well preserved and easily determined[4]; *T. angulata* ranges from the Middle Eocene to the Lower Oligocene of the East and occurs in the Upper Mokattam of Syria."

From Widan el Faras the series continues westwards, forming several escarpments, the uppermost that of Jebel el Qatrani, and maintaining the same general characters. The tripartite character of the series, already noticeable between Qasr el Sagha and Widan el Faras (see foregoing section) becomes still more marked. The lowest division is very

[1] Op. cit., p. 455-456. Vide Blanckenhorn, *Zur Kentniss der Süsswasserablag. u. Mollusken Syriens.* Palaeontographica XLIV, 1897, S. 97, t. 8, f. 2.

[2] More recently Blanckenhorn in a paper entitled *Nachträge zur Kentniss des Palaeogens in Ægypten*, (Centralbl. f. Mineralogie ch. 1901, No. 9, p. 272) has named this species *Lanistes bartonianus* (spelled *bartoninus* in same paper).

[3] It has 4-5 flat spiral rows, the uppermost of which on the last whorls is often more strongly developed but not keel-shaped as in *M. muricata*. There are longitudinal ribs to the number of 8-12 over the whorls; the largest example was 9 millimetres long and had 8 whorls.

[4] See Note 2, p. 43.

largely composed of fluviatile sands and sandstones, frequently coarse-grained and usually markedly current-bedded, divided by clays and containing an abundance of silicified trees and quantities of vertebrate remains. These soft beds, some 60 metres in thickness, have as a rule an extensive outcrop, forming an undulating plain averaging two or three kilometres in width. They are overlaid by some 17 metres of harder dark red sandstones, which invariably form a well-marked escarpment capped by a very constant two or three metres band of hard white or pinkish calcareous grit. This grit varies in composition, frequently passing into a marl; and one of the characteristics of this and the underlying red beds is the abundance of nodular masses of calcite and gypsum. In some localities, as for instance 3 kilometres W.N.W. of Qasr el Sagha, numerous spherical nodules of beekitic chalcedony occur in the beds of this division, and some of these when broken are found to be geodes lined with beautiful crystals of quartz and calcite.

The next division consists of some 60 metres of alternating sandstones and clays with occasional thin calcareous bands in the upper part, and capped by a well-marked hard cherty limestone, frequently passing into a dense tabular chert or flint. This exceptionally hard band generally forms a dip-slope plain of some width, before the softer basal members of the third and highest division overlie it. The siliceous bed caps many of the most notable hills in the district; among others may be mentioned the big isolated hill 9 kilometres north-west of Garat el Esh, and the hills five kilometres N.N.E. of the same point. This is the only horizon throughout the Eocene succession of the Fayûm on which an abundance of flint is met with; that it was well known and exploited in early times is evident from the old pits met with on the summits of the hills overlooking the main bone-pits, a few kilometres north of Garat el Esh. As no worked flints were noticed round the workings it is probable that the material was excavated and carried away to the borders of the lake, there to be fashioned into the harpoons, saws and other implements which are so commonly found scattered at the present day near the margin of the old lake site.

The uppermost division of the Fluvio-marine series consists of over 100 metres of variegated sediments and forms the escarpment of Jebel el Qatrani itself, capped by the conspicuous band of hard black basalt, which is itself overlain by a further 20 metres of similar sediments. The basalt has a thickness of over 20 metres in places, though its average is considerably less; at the base it is frequently decomposed, soft, and of a brown colour.

At a point due north of the western end of the Birket el Qurûn the interbedded basalt sheet terminates, and no further flows were seen as far as the point up to which the series was mapped, nearly due north of Gar el Gehannem. As far as could be seen on a traverse through the Zeuglodon Valley to the south-western limits of the depression no further basalt flows occur.

Section from the base of the Fluvio-marine series, 2 kilometres north of Garat el Esh, to the summit of Jebel el Qatrani $5\frac{1}{2}$ kilometres north of the bone-pits. (See Plates XVIII and XXIV).

		Approximate thickness in metres
Summit of plateau.		
1.	Coarse sandstones and grits...	13
2.	Basalt...	25
3.	Yellow sands and sandstones, capped by 3 m. of hard concretionary grey sandstone with occasional mammalian bones (underlying basalt in scarp and capping outlying hill)	15
4.	Hard sandstones with clayey bands...	8
5.	Sandy and clayey beds...	5
6.	Hard yellow calcareous grit...	5
7.	Clays and clayey marls ...	7
8.	Sandy beds	15
9.	Hard sandstone (forms connecting ridge between hill and escarpment)	$\frac{1}{2}$
10.	Clays with thin sandstone bands...	
11.	Variable sandy and marly red clays with a hard yellowish sandstone band ten metres from base	40
Base of isolated hill.		
12.	Soft sands with chelonian and crocodilian remains...	4
13.	Sandy clays with chelonian and mammalian (*Arsinoitherium*) bones, capped by coarse grit, in part ferruginous silicified grit and quartzite	1
14.	White calcareous grit and marly limestone. Band of flint in places...	
Summit of hill overlooking bone-pits.		
14.	Sandstone, becoming calcareous and passing up into 3 m. of hard white calcareous grit, and yellowish white bedded marly limestone with calcite druses. Capped by $\frac{1}{4}$ m. hard tabular chert and flint	10
15.	Finely laminated grey shaly clays, sandy and marly clays, capped by 2 m. of mottled yellow and red sandstone and sandstone-grit...	10
16.	Hard red, green, and brown sandstone	
17.	Variegated grey, green and red clays, marly clays and sandy beds, with thin bands of sandstone. More arenaceous towards top	21
18.	Hard grey sandstone; greenish sandy clays; hard dark red marls and marly clays at top	6
19.	Thin band of hard yellow limestone, capping salty red clays and sandy clays...	6
20.	Soft greenish clayey sandstone capped by $\frac{1}{2}$ m. of hard false-bedded concretionary sandstone with numerous enclosed coprolites	3
Base of hill overlooking bone-pits.		
21.	Pink calcareous grit (forming summit of lowest escarpment), with small flint and quartz pebbles in some layers. An abundance of calcite and gypsum	3
22.	Mottled red and green clayey sandstone, clays and clayey marls. Passing up into a hard sandy (or clayey) dark red marl with greenish mottlings ...	7
23.	Light yellow finely-laminated sandrock passing up into dark red sandrock. Some clayey bands...	10
24.	Coarse unconsolidated false-bedded sands, with occasional bands of clay and consolidated sandstone bands. Numerous silicified trees and abundant mammalian and reptilian remains. (See list in Bed 49 of Widan el Faras section). Bone-pits are in this bed	40
25.	Thin band ($\frac{1}{2}$ m.) of hard sandstone with sometimes impure calcareous grit	10
26.	Hard light yellow sandstone, often very coarse, and with red bands ...	
27.	Soft brick red and light yellow sands and sandstones, (seen on plain and overlying uppermost limestone of the Middle Eocene)	20
Base of Fluvio-marine Series.		

SILICIFIED TREES OF FLUVIO-MARINE SERIES, 4½ KILOMETRES NORTH OF QASR EL SAGHA.

In some localities pebbly bands occur in the sandstone-grits, especially in some of the beds above the basalt; the pebbles are mostly quartz or flint, subangular or rounded, the layer averaging perhaps two cm. in diameter, although occasional specimens three or four times that size are met with. Silicified trees of two distinct types[1] occur, and they are met with chiefly on two horizons; usually large numbers of trees occur together, completely covering the surface in places; they lie as a rule scattered about in every direction, although occasionally a large proportion may show considerable parallelism of deposition, as if arranged by the direction of the current which floated them to the spot. They always occur in a horizontal position or parallel to the dip of the bed, and it seems quite certain that none of them ever grew near where they are now found. The trees never bear attached branches, the latter having always been broken off at or near the point of junction with the trunk, where the scars are often plainly seen; this points to the trees having been drifted a considerable distance. Many trees over 25 metres[2] in length have been met with, but this by no means represents the original height, as the trunks have lost considerably in length during transport to their present localities. Although, as a rule, found completely weathered-out and exposed on the surface, in numerous localities these silicified trees are to be observed firmly embedded in the sandstones in which they were deposited, many being met with in our excavations for bones.

As the Fluvio-marine series is followed westwards from the central part of the area, the different divisions become more and more attenuated and the outcrops more and more obscured by superficial gravel. North-west of the Zeuglodon Valley an escarpment capped by a conspicuous bed of white calcareous grit occurs and perhaps represents the lower beds of the series. The higher are lost on the gravelly undulating plateau above.

F.—Age of the "Fluvio-Marine Series".

The beds in question being as a whole remarkably unfossiliferous, a determination of their exact age on palaeontological grounds is an undertaking of some difficulty. The series, however, in certain beds is very rich in vertebrate remains; a considerable number of new and important forms have already been obtained and further additions are probable. Until the survey of the area in 1898 it appears that the only fossils obtained from these rocks were a few casts and badly-preserved specimens of mollusca from the highest beds above the basalt, collected by one or two observers from localities between the summit of the Fayûm escarpments and the Pyramids of Giza.

The Rohlfs Expedition did not visit this part of Egypt, and Zittel[3] tabulated the beds, which he called the "Schichten von Birket el Qurûn" as doubtfully Oligocene; probably the beds referred to are those of the island Geziret el Qorn, which, as already mentioned,

[1] The majority belong to the genus *Nicolia*, but more rarely specimens, apparently referable to a species of conifer, are met with.

[2] The largest trunk noticed had a length of 28 metres.

[3] ZITTEL, *Beitr. z. Geol. u. Palaeont. d. Libysch. Wüste*, I Th. (Palaeontographica, Vol. XXX) p. XCIII.

belong to the lower division of the Birket el Qurûn series, and are therefore of Middle Eocene age. Mayer-Eymar[1] states that he was able to subdivide the series under discussion into Upper and Lower Ligurian and Lower Tongrian. Schweinfurth[2] considered the series as Miocene, comparing them with the lithologically similar *Scutella* beds of Der el Beda to the east of Cairo. Blanckenhorn, on the evidence of the writer's fossil collections, states, as already mentioned, that the upper part is certainly to be regarded as Lower Oligocene and the lower part as Upper Eocene.

First as to the stratigraphical position of the series. There is no doubt that the lowest beds of the group were deposited (at any rate in the central part of the area) in practical continuity with the Qasr el Sagha series, which, as shown, is certainly of Middle Eocene age. A great change in the lithology of the beds, however, makes the junction a perfectly natural one. We pass from a truly marine series into an estuarine or fluvio-marine set of beds, and such a change near the summit of the Eocene is not an uncommon one in some parts of Europe. The stratigraphical position in the field, therefore, favours an Upper Eocene age for the lower beds. The dip being northwards, newer and newer beds are met with from south to north on the great undulating, but more or less level, desert north of the escarpment summit. The occurrence of Lower Miocene beds at Mogara, some 100 kilometres north or north-west, also points to a somewhat younger, or Oligocene, age for the underlying beds, (i.e., those between the Fayûm escarpment and Mogara). The actual relations, however, of the beds in the two localities have not yet been determined, but it is probable younger beds are continually met with from south to north.

Until the entire collection of fossils has been examined and determined, it is somewhat premature to attempt to fix the age of the series on palaeontological grounds. Up to the present the foregoing lists show the species which have been provisionally or finally determined. Some of these appear to be identical with species which have been recorded from Upper Eocene deposits of Europe, such as *Potamides scalaroides*, *P. tiarella*, while others, such as *Melania* cf. *Nysti*, *Natica crassatina* (found below the basalt in the so-called Sandberger Hills north-east of the Fayûm escarpment), are typically Lower Oligocene. Other forms, such as *Turritella angulata*, are common to both Eocene and Oligocene elsewhere.

If Blanckenhorn's determinations of these forms are confirmed, we may regard the upper beds, i.e., those immediately above the basalt, as undoubtedly of Lower Oligocene age. The beds below the basalt mark the transition from the Eocene to Oligocene, while the base of the series, so far unfossiliferous as far as molluscan remains are concerned, must be regarded as of Upper Eocene (Bartonian) age.

[1] MAYER-EYMAR, *Quelques mots sur les nouvelles recherches relatives au Ligurien et au Tongrien d'Egypte.* Bull. de l'Inst. Egypt. (3) N. 4, 1894. Mayer-Eymar's division of the lower beds into *Ligurien inférieur* and *Ligurien supérieur* is hardly convincing, especially as no fossils were found by that observer. The correlation of strata in widely separate areas by their lithological similarity is at least open to question, especially with beds of this type, which can indeed be exactly matched again and again at many levels in the same vertical succession. His diagnosis of the beds immediately below the basalt as *Tongrien inférieur*, rests, however, on firmer grounds, as this basalt sheet can be traced across the desert to beyond the latitude of Cairo, and is probably everywhere of approximately the same age.

[2] SCHWEINFURTH, op. cit. *Reise in das Depression Gebiet*, etc.) p. 41.

We may hope that when the important vertebrate fauna occurring chiefly in the basal part of the series has been thoroughly exploited, and the remains systematically determined, confirmatory evidence will be obtained. At present the only forms described and determined, beyond pointing to a pre-Miocene age, do not indicate any definite horizon. Probably most of the animals will prove to be new, and although on that account more interesting from one point of view, will probably not assist us greatly in the exact determination of the age of the beds in question.

G.—The Position of the Land-mass from which the Mammal Remains were Derived.

The existence of remains of land animals throughout the larger part of the Qasr el Sagha series and in still greater quantity in the basal beds of the overlying Fluvio-marine series, and occasionally in the highest beds also, points to the presence of continental land within no great distance of the area in which these deposits were laid down. That the animal-remains were carried out from the land by river currents is almost certain, and although in some cases such currents are known to persist to great distances from their points of emergence, it seems probable from the quantity and mode of distribution that the Fayûm bones were deposited within a moderate distance of land. Moreover, the silicified trees, by which the bones are so often accompanied, occur together in very great quantities, and we should imagine that the individual trees would have been far more scattered if they had been floated to considerable distances from land. On the other hand the fact that among the hundreds of trees examined, in no single case were branches found attached to the trunk, points to the conclusion that these trees had travelled great distances; probably the branches were lost during their river journey, from constant jamming together of a great number in a more or less constricted space, and not after they had left the river mouth.

The exact position of this land-mass is a highly interesting and important question. There is no reason to suppose that land of any extent occurred to the north, except possibly an occasional island, such as that of the Cretaceous massif of Abu Roash,[1] west of Cairo, which probably formed an island in the sea at that time; without doubt the great Eocene sea which covered the area stretched northwards, and was continuous with that in which the southern European deposits of this period were laid down. To the west also there was certainly no land-mass within approximate distances. Eastwards, possibly part of the Red Sea Hills igneous range may have formed a restricted land-area, but even this is not probable; in fact, it seems certain that we must look to the south for the nearest land of any extent. In supposing the land lay in this direction we are confronted at the outset with the fact that the Lower Eocene limestones stretch southwards for several hundred kilometres. In Egypt the Lower Eocene consists of a great mass of nummulitic limestones, some 400-500 metres thick, with no intercalated clays or sandstones except at the base, and was evidently formed in water of considerable depth. The thickness of, and superficial area covered by, these

[1] BEADNELL. *The Cretaceous Region of Abu Roash, near the Pyramids of Giza.* Geol. Survey. Egypt, Report 1900, Pt. II. 1902, p. 44.

limestones show that they were formed in a truly open sea, in contra-distinction to a littoral area; the nummulitic sea in fact covered an enormous part of Europe, North Africa and Asia. To the south of this sea lay the African continent, a land-mass dating possibly from Palæozoic times. Since, and possibly partly during, the deposition of the Lower and Middle Eocene formations, a gradual elevation of the land or lowering of the sea, resulting in a retreat of the latter, took place; this continually brought the shore-line further northwards until, during the deposition of the beds of the Qasr el Sagha series of the Middle Eocene, we may surmise that it was not very far to the south, though the exact distance is extremely doubtful; while in Upper Eocene times it was still further north. We may assume therefore that the Upper Eocene bone-bearing strata of the Fayûm represent sediments transported by rivers and currents from a fairly adjacent continental land-mass to the south and laid down as littoral and delta deposits beyond the margin of the land. That at least one large river emerged from the land in the neighbourhood of the Fayûm is certain; drainage was then, as now, from south to north, although not probably confined to a single channel like the present Nile.

Apart from broader considerations a minute examination of the more typically fluviatile beds favours the conclusion that the currents were from the south or south-west. The general dip of the strata, probably the natural inclination of the sediments at the time of deposit, is from south to north; the most frequent lamination in the current-bedded arenaceous deposits is also from south to north. In our excavations for fossil bones it was noted that of seven tortoise shells exposed at the same time in different parts of the pit, six lay with their long axes similarly orientated and were distinctly tilted to the north-east, or exactly away from the point of the compass from which, as will presently be shown, the main river probably came. As a rule, however, the scattered fossil bones and trees in these beds give no definite clue as to the direction from which they were floated. The existence of separate accumulations of fluviatile sand at different horizons, but lying one above the other in the series and along a north and south line, is of importance as indicating the continued appearance of a river current from the same quarter.

Blanckenhorn has published[1] diagrams showing what he supposes to have been the relative areas occupied by land and sea in Upper Mokattam, Lower Oligocene, Middle Pliocene and Pleistocene times. Various lines of drainage are shown, the main river, which he calls the Ur-Nil, being placed some 70 kilometres to the west of the modern Nile, although closely following the trend of the latter. We have been unable to ascertain on what evidence Blanckenhorn relies for assuming rivers in Upper Mokattam and Lower Oligocene times to have occupied the positions shown on his diagrams; the number and positions of such rivers must remain more or less problematical. In this connection however it is interesting to recall[2] the lacustrine ferruginous grits which were brought to notice by the writer in 1900

[1] *Zur Geologie Aegyptens*, Pt. II, p. 458; *Die Geschichte des Nil-Stroms in der Tertiär und Quartärperiode*, etc., Z. d. Ges. f. Erdk. Z. Berlin, 1902, Tafel 10.

[2] BEADNELL, *Découvertes Géologiques Récentes dans la Vallée du Nil et le Désert Libyen*, Compte rendu. VIII^{e} Congr. Géol. Internat. 1900, Paris, 1901, p. ; also BALL and BEADNELL, *Baharia Oasis: Its Topography and Geology;* Survey Depart. P. W. M. report, Cairo, 1903, pp. 61-62.

as having been deposited in a lake, occupying in post-Middle Eocene times a shallow depression in that part of the Libyan desert now occupied by the oasis-depression of Baharia. Similar deposits were found forming the hills of Gar el Hamra a few kilometres east of the extreme north end of the depression. Finally, during a traverse through the unexplored country south-west of Gar el Gehannem in the winter of 1902-1903, hills capped with dark hard ferruginous silicified grits and puddingstone were met with in the extreme south-west of the Fayûm depression at a point nearly midway, and in the direct line, between the hills of Gar el Hamra and the chief bone-bearing localities in the north of the Fayûm. The deposits in question—at Baharia, at Gar el Hamra and in the hills to the south-west of the Fayûm—are evidently of lacustrine and fluviatile origin; and we may infer, with some degree of probability, that they were laid down along the course of a river which flowed in a north-easterly direction and formed extensive delta deposits in what is now the northern part of the Fayûm. That this river had its origin in the interior of a well-wooded continent hundreds of miles to the south of Baharia is not to be questioned; its size, length and exact position must remain matters of doubt, but of its existence we can be as certain as if in times of flood we had stood on its banks and watched the passage northwards of its turbid swollen waters, laden with matted rafts of forest trees and bearing seawards the carcases of those curious Eocene animals, the remains of which are so abundant in the Fayûm of to-day.

FIG. 6.—Probable Course of chief river of Upper Eocene and Oligocene times.

In the Middle and Upper Eocene beds we first obtain an idea of the animals which inhabited Africa in Tertiary times, and the collecting and working out of this fauna will

throw much light, not only on our actual knowledge of the African vertebrata of the Eocene period, which was practically nil until the discovery of the remains here described, but also on other wider biological questions, such as the origin of certain groups of animals, some of which were evolved in this part of the world.

As recently pointed out by a writer in the Field (No. 2605, Nov. 29, 1902) many years ago the late Prof. Huxley, to account for the present distribution of the mammalian fauna of Africa and Magadascar, advanced the theory that in the early part of the Tertiary period Madagascar was connected with Africa, and Africa with Europe or Asia, a connection which allowed of the immigration into Africa and Madagascar of numerous small types of European and Asian mammals. Madagascar later becoming separated from the mainland, its fauna, undisturbed by the larger carnivora, was able to develop to its present remarkable extent. Subsequently to the isolation of Madagascar the ancestors of the modern fauna were presumed to have invaded the African continent from the north.

The extinct fauna of the Fayûm, however, shows that in early Tertiary times Africa already had its own mammalian fauna, which, besides containing some remarkable large types of somewhat doubtful position, such as *Arsinoitherium*, *Barytherium*, etc., certainly in *Mœritherium* and *Palæomastodon* included the earliest known elephants, the forbears of the Mastodon and the modern elephants. There is little doubt therefore that in Upper Eocene and Oligocene times these early members of the elephant group ranged northward and eastwards into Asia and India, and since in the Upper Tertiary deposits of India and eastern Asia the extinct transitional types between the mastodons and modern elephants appear to have been found, it is not unlikely that during the later phases of the evolution of this group of animals the radiation was back towards Africa, so that the African elephant may be, as it has usually been regarded, an immigrant from the Oriental region. Further research among the later deposits of the Fayûm and the deserts to the north may, however, throw an entirely new light on the subject and it is somewhat premature to theorise at present.

In this connection it is interesting to notice the observation of so eminent a palæontologist as Prof. H. F. Osborn. In two recent addresses[1] to the New York Academy of Sciences he pertinently points out his belief that the African continent has been a great centre of radiation of certain groups of the mammalia, and especially mentions the Proboscidea as likely to have been evolved in the Ethiopian region. Our discoveries in the Fayûm and Andrews's determinations, made subsequently to these addresses, so completely confirm this view, at any rate with regard to the elephants, that it may not be out of place to give here a somewhat lengthy extract of his "*Theory of Successive Invasions of an African Fauna into Europe*" (op. cit. pp. 56-58). "In Europe there are in the Upper Eocene two classes of animals, first those which have their ancestors in the older rocks; second, the class including certain highly specialized animals which have no ancestors in the older rocks, among these, perhaps, are the peculiar flying rodents or *Anomaluridæ*, now confined to Africa, and secondly the highly specialized even-toed ruminant types the

[1] *Correlations between Tertiary Mammal Horizons of Europe and America*, Annals N.Y. Acad. Sci., Vol. XIII, No. 1, July 21, 1900, pp. 1-72.

RAISED BEACH UNCONFORMABLY OVERLYING MIDDLE EOCENE LIMESTONES (BIRKET EL QURUN SERIES) IN THE DESERT EAST OF SIRSENA.

anoplotheres, xiphodonts and others, the discovery of which in the gypse near Paris Cuvier has made famous. It is tempting to imagine that these animals did not evolve in Europe but that they represent what may be called the first invasion of Europe by African types from the Ethiopian region.

" It is a curious fact that the African continent as a great theater of adaptive radiation of Mammalia has not been sufficiently considered. It is true that it is the dark continent of palæontology for it has no fossil mammal history; but it by no means follows that the Mammalia did not enjoy there an extensive evolution.[1]

" Although it is quite probable that this idea has been advanced before, most writers speak mainly or exclusively of *the invasion of Africa by European types.* Blanford and Allen, it is true, have especially dwelt upon the likeness of the Oriental and Ethiopian fauna, but not in connection with its antecedent cause. This cause I believe to have been mainly an invasion from south to north, correlated with the northern extension of Ethiopian climate and flora during the Middle Tertiary. It is in a less measure due to a migration from north to south. Let us therefore clearly set forth the hypothesis of *the Ethiopian region or South Africa as a great center of independent evolution* and as the source of successive northward migrations of animals, some of which ultimately reached even the extremity of South America, I refer to the Mastodons. This hypothesis is clearly implied if not stated by Blanford in 1876 in his paper upon the African element in the fauna of India.

" The first of these migrations we may suppose brought in certain highly specialized ruminants of the Upper Eocene, the anomalures or peculiar flying rodents of Africa; with this invasion may have come the pangolins and ard varks, and possibly certain armadillos, *Dasypodidæ*, if M. Filhol's identification of *Necrodasypus* is correct. A second invasion of great distinctness may be that which marks the beginning of the Miocene when the mastodons and dinotheres first appear in Europe, also the earliest of the antelopes. A third invasion may be represented in the base of the Pliocene by the increasing number of antelopes, the great giraffes of the Ægean plateau and in the upper Pliocene by the hippopotami. With these forms came the rhinoceroses with no incisor or cutting teeth, similar to the smaller African rhinoceros, *R. bicornis.* Another recently discovered African immigrant upon the Island of Samos in the Ægean plateau is *Pliohyrax* or *Leptodon*, a very large member of the Hyracoidea, probably aquatic in its habits, indicating that this order enjoyed an extensive adaptive radiation in Tertiary times.

" It thus appears that the Proboscidea, Hyracoidea, certain edentata, the antelopes, the giraffes, the hippopotami, the most specialized ruminants, and among the rodents, the anomalures, dormice and jerboas, among monkeys the baboons, may all have enjoyed their original adaptative radiation in Africa; that they survived after the glacial period, only in the Oriental or Indo-Malayan region, and that this accounts for the marked community of fauna between this region and the Ethiopian as observed by Blanford and Allen.

[1] Compare *Afrika als Entstehungszentrum für Saügetiere*, Stromer, Zeitschr. d. Deutsch. Geolog. Gesellsch. Jahr 1903. Also *Betrachtungen über die Geologische geschichte Aethiopiens*, do. do., 1901.

"Against the prevalent theory of Oriental origin of these animals are: first, the fact observed by Blanford and Lydekker in the Bugti Beds (Sind) that the Oligocene or lower Miocene fauna of the Orient is markedly European in type; second, that if these animals had originated in Asia some of them would have found their way to North America; third, the fact that all these animals appear suddenly and without any known ancestors in older geological formations. These are the main facts in favor of the Ethiopian migration hypothesis."

That Professor Osborn's main contention has already been partly proved by the Fayûm mammal discoveries is apparent, and how far his detailed remarks are confirmed will be seen when the new fauna has been more completely explored and examined.

The following is a list of the new species already obtained:—

UPPER EOCENE.	MIDDLE EOCENE.
Mammalia	
Arsinoitherium Zitteli, Beadnell. ,, Andrewsii, Lankester. Palæomastodon Beadnelli, Andrews. ,, minor, ,, Mœritherium Lyonsi, ,, ,, trigodon, ,, Megalohyrax eocœnus, ,, ,, minor, ,, Saghatherium antiquum, Andr. and Beadn. ,, minus, ,, ,, ,, magnum, Andr. Ancodus Gorringei, Andr. and Beadn. Geniohyus mirus, Andr. ,, fayumensis, Andr. ,, major, ,, Phiomia serridens, Andr. and Beadn. Pterodon africanus, Andr. ,, macrognathus, Andr. and another much smaller and imperfectly known creodont.	Barytherium grave, Andr. Mœritherium Lyonsi, Andr. ,, gracile, ,, ,, sp., ,, Eosiren libyca, ,, Zeuglodon Osiris, Dames. ,, Zitteli, v. Stromer. ,, Isis, Beadn. (M. S.).
Birds.	
Eremopezus libycus, Andr.	
Reptiles.	
Testudo Ammon, Andr. Pelomedusa progaleata, v. Reinach. Podocnemis fayumensis, Andr. ,, Blanckenhorni, v. Reinach. ,, ,, var. ovata, v. Reinach. Stereogenys libyca, Andr. Tomistoma sp. Crocodilus sp.	Gigantophis Garstini, Andr. Pterosphenus (Mœriophis) Schweinfurthi, Andr. Psephophorus eocœnus, Andr. Thalassochelys libyca, Andr. Podocnemis antiqua, ,, ,, Stromeri, v. Reinach. ,, ,, var. major, v. Reinach. Stereogenys Cromeri, Andr. ,, podocnemioides, v. Reinach. Tomistoma africanum, Andr.
Fish.	
Occasional fragments of siluroids and rays.	Propristis Schweinfurthi, Dames.

H.—The absence of Miocene deposits in the Fayûm.

No traces of deposits of this age having been met so far south as the Fayûm we may presume that in Miocene times the area had become land, the sea margin having receded northwards. The slight depression of Mogara, some 100 kilometres further north-west, is however cut out in Lower Miocene beds, lithologically somewhat similar to the Upper Eocene and Oligocene deposits of the Fayûm. Probably similar conditions obtained throughout, and the existence of vertebrate remains indicates the persistence of river-currents from the south. The fauna of the Mogara beds has only as yet been very incompletely examined, the locality being rather inaccessible.[1]

Section XII.—PLIOCENE.

We have presumed that in Miocene times the Fayûm remained land, no traces of deposits of that age having been recorded; possibly the area underwent considerable denudation during the Miocene and early Pliocene periods, but of this it is difficult to adduce definite evidence. The records of Pliocene times in the Fayûm may be classed as follows:—

(J). *Marine deposits* of Middle Pliocene age.
(K). *Borings* on rock surfaces, exact age doubtful.
(L). *Gravel Terraces*, probably late Pliocene. } (or early Pleistocene).
(M). *Gypseous Deposits*, probably latest Pliocene. }

J.—Marine Deposits : Middle Pliocene.

In Middle Pliocene times the area, which had probably undergone considerable denudation, was again invaded by the sea, and we find at Sidmant el Jebel, on the south-east side, definite evidence of deposits of this age in the shape of sands containing such well known forms as *Ostrea cucullata* and *Pecten benedictus*.

The beds in question reach an altitude of from 60 to 70 metres and were first brought to notice by Schweinfurth. Although they are in reality on the Nile Valley side of the separating ridge or saddle, there is little doubt that the same beds will, when looked for, be found within the Fayûm depression in places where they have been preserved. As has already been mentioned this south-eastern side of the Fayûm yet remains to be examined and mapped in detail, and the determination of the relation of these marine sands to the gravel terraces shortly to be described is a matter of primary importance for the proper interpretation of their relative ages.

K.—Borings on Rock surfaces; of doubtful age.

There are within the Fayûm depression numerous rock-surfaces pierced by borings, apparently the work of marine boring mollusca but naturally offering no exact evidence as

[1] The locality has been briefly examined by Dr. Blanckenhorn and more recently by Mr. T. Barron, who was accompanied by Dr. Andrews; the writer spent a few days collecting in the neighbourhood in April, 1903.

to their age and origin. These borings are found at two distinct levels, approximately from zero to 20 metres above sea-level, and at 112 metres above sea-level.

(α) *Low level borings.*

Between Tamia and Dimê, near the eastern end of the Birket el Qurûn, the lowest ground, consisting of poor sandy land with tamarisk scrub, bordering the lake and cultivation, is bounded by a low escarpment of beds of the Birket el Qurûn series. Along certain horizons one or more beds of calcareous sandstone weather into large globular masses, which as already pointed out are in reality huge concretions, but which may have been further rounded by water-action. The chief point is, however, the fact that these blocks are honey-combed in the most remarkable way by beautiful examples of borings; their presence was first noticed by Schweinfurth. The globular masses of sandstone, often several feet in diameter, are worn on the surface into a number of parallel ledges, each of which is perforated with countless numbers of vertical holes, averaging 10 millimetres in diameter (maximum 15 millimetres), placed at right angles to the ledges; these holes are not, as a rule, connected from one ledge to another. They occur in every stage of perfection, from hollows as small as the finger tips and only a few millimetres deep, to long completed chambers which generally show considerable tapering, and are often placed so close together that the dividing wall is pierced.

Fig. 7 and Plate XIII show the appearance of these bored rocks.

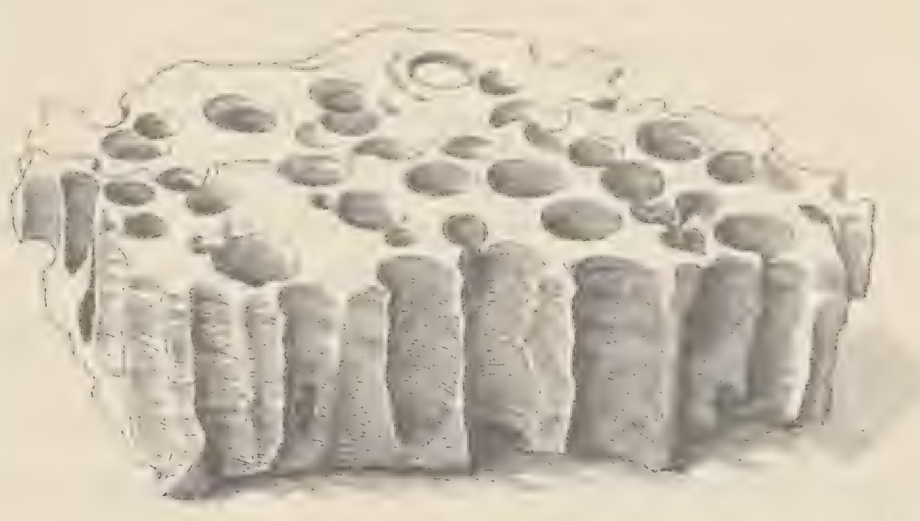


FIG. 7.—Block of sandstone pierced by numerous borings.

At El Kenîsa, a promontory jutting out into the lake, sandstones showing shell-borings occur at a height of 14 metres above sea-level. Between Dimê and the lake a calcareous sandstone contains many borings, 66 metres above the lake-level, or about 22 metres above sea-level.

BORINGS IN FALSE-BEDDED SANDSTONE, TWO KILOMETRES SOUTH OF DIMÊ.

(β) *High level borings.*

Further west, but at a considerably higher level, borings are again met with. In this case a hard compact limestone, forming a dip-slope surface on the top of the lower cliff of the Qasr el Sagha series, was found pierced with borings, similar in character to those of the lower level. The exact locality where these high level borings were observed is 14 kilometres west of the western end of the lake and 16 kilometres north-east of the eastern extremity of Gar el Gehannem. The height was determined as 156 metres above the Birket el Qurûn, or 112 metres above sea-level, and we have every reason to believe these figures to be approximately correct. Up to the present time borings at this altitude have not been met with in any other locality.

At first sight it seems surprising that the occurrences should be so limited, but it should be remembered that only in those cases where borings were made in the very hardest and most durable rocks could they have been preserved to the present time. Considering the amount of denudation which has taken place in the area since the Pliocene period it is surprising that any of the rocks which formed the actual surface of the country at that date should still be preserved; and in all probability the comparatively few records that exist to-day owe their preservation to the protection afforded by superficial deposits. Under the present rigorous desert conditions, when the whole surface is subjected to continual and rapid changes of temperature, and every exposed rock is being worn down by the natural sandblast, it must be admitted that in a comparatively short time every trace of the borings now exposed will have been removed. At the same time the denudation of superficial deposits will probably lay bare other bored rock-surfaces, and the conserving nature of drift sand itself where accumulated to even a limited degree must not be forgotten.

L.—**Gravel Terraces : ? Upper Pliocene.**

On the north, east, and south-east sides of the Fayûm, well marked terraces of gravel are found at certain levels up to a maximum of about 170-180 metres above sea-level. Nine kilometres east of Sêla the summit of the ridge separating the Fayûm and the Nile Valley is formed of thick deposits of gravel, laid irregularly and unconformably on the top of limestones belonging to the Birket el Qurûn series. The lowest terrace occurs only 15 metres above the canal[1] running along the outside of the cultivation. The main deposit of gravel is laid on the top of the limestones and marls at 70 metres above the canal; it is some 50 metres thick (summit 120 metres above canal) and consists of a mass of well-rolled flint and quartz pebbles, with blocks of limestone (frequently full of well-known Eocene fossils such as *Carolia placunoides*). Large well rounded blocks of grey quartzite and pebbles of black quartzite also occur, besides rounded blocks of silicified wood. A certain amount of false-bedding occurs and false-bedded sand was noticed in places. Numerous derived rolled fossils are present, but no contemporaneous remains

[1] Approximately 10 metres above sea-level.

were found. On the summit of the ridge is situated the remnant of an old pyramid-like building.

Fig. 8 shows the relation of these gravels to the underlying rocks.

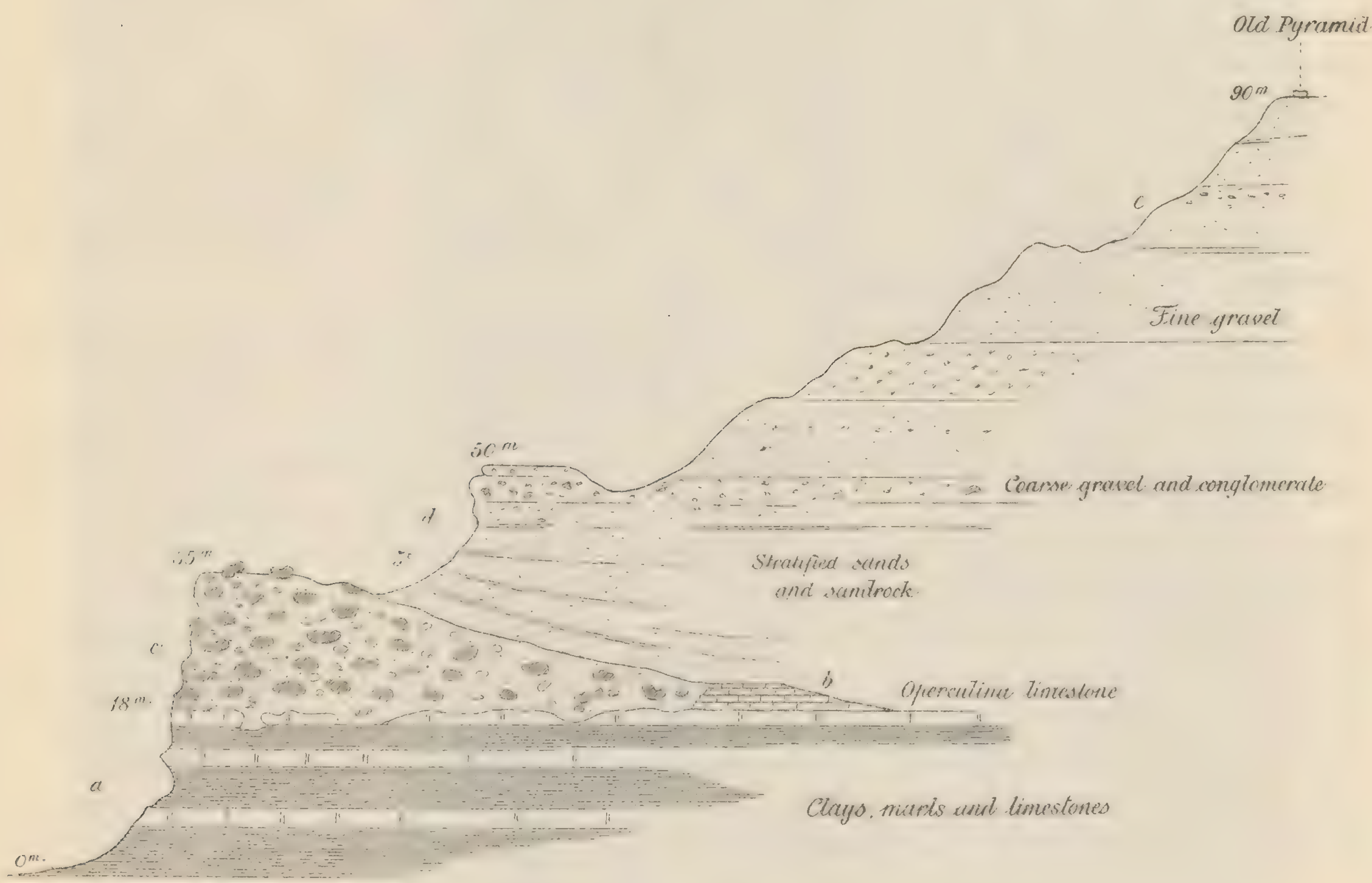


FIG. 8.—*Sketch showing relations of Middle Eocene to Pliocene Gravel Terraces on the east side of the Fayûm.*

Birket el Qurun series.—(*a*) Clays, marls and limestone; (*b*) Limestones with *Operculina* (*O. discoidea?*). *Pliocene (to Pleistocene)*; (*c*) Coarse deposits of gravel, etc., with huge blocks of derived Eocene limestone with *Carolia*, etc.; (*d*) sands and sandrock with leaves of hard sandstone; (*e*) sand, gravel and conglomerate.

At the spur of the cliff immediately to the east the terrace is laid on to limestones of the Birket el Qurûn series at a height of 32 metres above the canal. Enormous blocks of *Carolia*-limestone, some exceeding $3 \times 2 \times 1{\cdot}5$ metres in measurement, are included in this deposit; such blocks cannot have been transported far, and were doubtless derived from formerly-existing higher beds in the immediate neighbourhood. The matrix of the deposit is usually crushed limestone with sand and gravel. Occasional fragments of silicified wood (and further west large logs), evidently derived from the Fluvio-marine beds, also occur.

In favoured localities the relation of the gravels to the Eocene is still better seen; the lower beds of the terrace here are sometimes formed of sands and sandy beds dipping 10° eastward.

At the little promontory 9 kilometres east of Sersena the same deposits reach an altitude of 157 metres above the canal below.

Further north another cake of gravel caps the summit, attaining here 60-70 metres above the canal-level. Probably these deposits were originally more or less connected and continuous, but since their deposition denudation must have removed the greater part, as they are now only found here and there capping the highest points of the escarpment along the east side of the Fayûm. Such isolated gravel-capped hills occur notably 12 kilometres east of Roda, 16½ kilometres east and 17½ kilometres north-east of Tamia.

Along the north side of the Fayûm the same deposits are found, in some cases covering large areas.

Twenty-five kilometres N.N.E. of Tamia the Eocene beds, here an alternating series of clays and limestones, are capped by a deposit consisting of coarse rolled gravel, with blocks of silicified wood enclosed in a sandy gypseous base, some 10 metres thick. A larger and similar deposit caps the next high ground four kilometres to the west, and about 9 kilometres N.N.E. of Garat el Faras; in this case it forms a round-topped gravelly hill-range, attaining a height of about 165 metres above the canal to the south-east. The loose gravel at many points passes into hard conglomerate, notably in the hills 9 kilometres east and 4 kilometres north-east of Garat el Gindi. At the former spot the conglomerate is composed of blocks of limestone, with round pebbles of flint and quartz, sandstone and quartzite, and fragments of silicified wood, cemented by sand and calcareous material. Blocks of silicified wood also occur strewn on the surface of these gravel deposits.

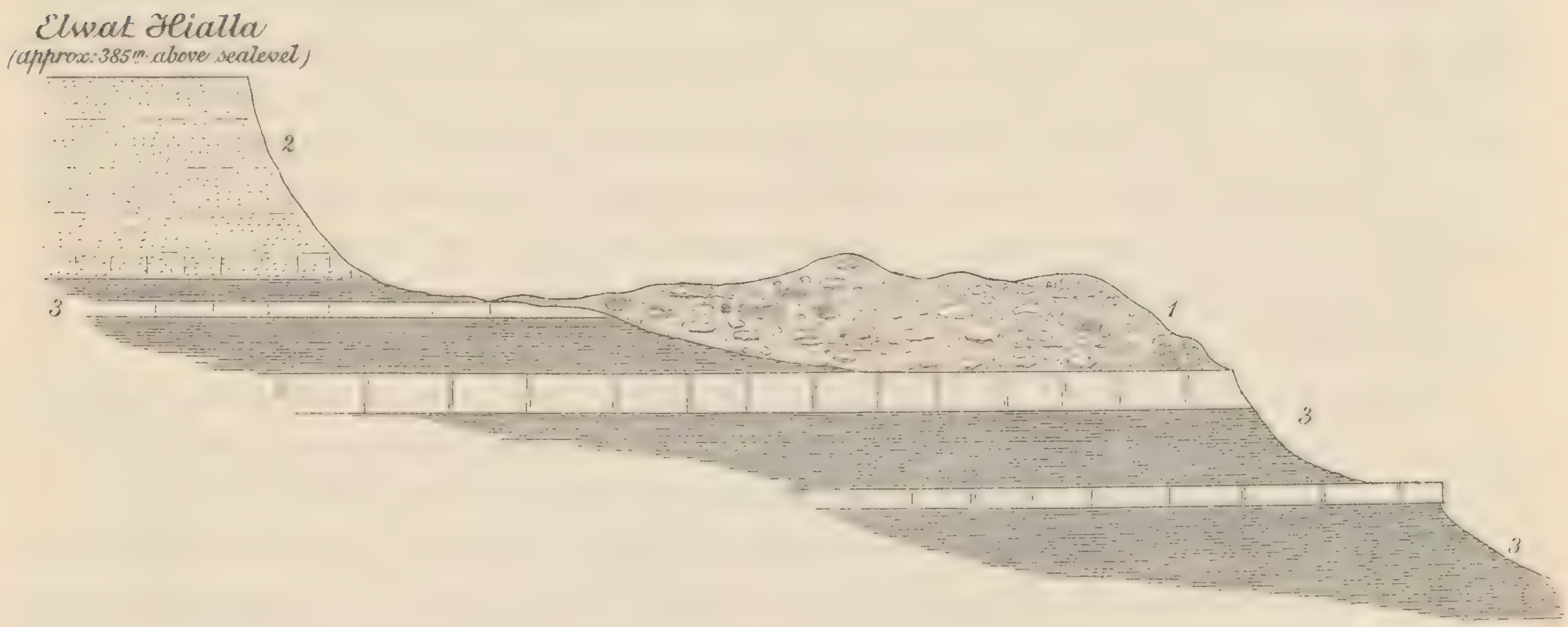
In the hills north-east of Garat el Gindi the gravel deposits do not occupy the summit of the escarpment but occur laid on to a platform of beds belonging to the Qasr el Sagha series. Behind, another escarpment, that of the Fluvio-marine series, rises to the plateau summit.

Fig. 9 will show the general relation of the different formations in this part of the district.

Near Elwat Hialla the deposits contain numerous blocks of basalt in addition to the usual constituents. The basalt is derived from the sheets interbedded at the base of the Oligocene a little to the north. As these gravels are here close to that formation, blocks of sandstone, basalt, and silicified wood now form a large proportion of the constituents.

Along the north side of the Fayûm depression, to the west of Elwat Hialla, the gravel terraces are almost absent, having been removed nearly completely by denudation. That the terraces once existed throughout this region is however shown by the small patches met with to the north-east of Widan el Faras, the eastern extremity of Jebel el Qatrani, and at several points high up on the escarpments as far west as the western end of the lake. Beyond the latter point these terrace gravels have not been noticed; the slopes of the depression

become more and more obscured by loose superficial flints washed down from the plateau, and the existence of underlying terrace gravels could only be shown by detailed mapping.



PLIOCENE (TO PLEISTOCENE) ....—1. ... Terrace of gravel and conglomerate.
UPPER EOCENE-OLIGOCENE.—2. ... Sands and sandstones.
MIDDLE EOCENE. ... ...—3. ... Clays, marls and limestones of the Upper Mokattam.

FIG. 9.—Sketch-Section through summit of Fayûm Escarpment at Elwat Hialla.

Near Widan el Faras the terrace occurs at a level of about 220 metres above the Birket el Qurûn, or 175 metres above sea-level, and consists of a 10-metre thickness of a semi-consolidated mass of boulders and pebbles of sandstone, limestone, and basalt, with fine gravel and sand, unconformably laid on to the variegated sandstones of the Fluvio-marine series.

In the neighbourhood of the Survey's main excavations for fossil bones, to the north of Garat el Esh, several local remnants of the formerly more or less continuous gravel terrace were detected[1]. The height was probably more accurately determined here than elsewhere and the upper limit of the deposits was found to lie at approximately 170 metres above sea-level; this figure may indeed be taken as the average height of the Pliocene terraces throughout the Fayûm.

[1] It is worth recording here that a single worn specimen of *Chicoreus anguliferus*, Lam., was found on the desert surface in the neighbourhood of the bone-pits and at about the level of the highest gravel terrace. This determination was made by Bullen Newton, who informs me the species occurs in the marine Pleistocene beach deposits of the Red Sea.

PLEISTOCENE LACUSTRINE CLAYS WITH TAMARISK STUMPS IN SITU AT 50 METRES ABOVE PRESENT SURFACE OF THE BIRKET EL QURUN.

Briefly then we have shown the existence of the well marked remains of a gravel terrace 170–180 metres above sea-level, throughout the south-east, east, and north sides of the Fayûm depression, and the first question that suggests itself with regard to these deposits is, whether they are of marine or of freshwater origin? From their position in part capping and in part perched on the flanks of the escarpments, it is evident that the depression of the Fayûm must have been partly formed before their deposition; probably it had approximately obtained to its present form and dimensions, except as to depth. The terrace certainly marks the shore-line of the sheet of water in which its constituents were deposited, and the surface of this water must have attained a height of nearly 200 metres above present sea-level. It is not unlikely that some of the extensive plains of the Fayûm may owe their existence in part to the presence in Pliocene times of the sea or of a large inland lake, that they may in fact be plains of denudation. The plain above the escarpment of the Qasr el Sagha series, lying between 150 and 200 metres above sea-level, and stretching throughout a large part of the north of the Fayûm, has characters which tend to support this idea.

Unfortunately the gravels are entirely barren of contemporaneous organic remains, with one exception; near Ez. Qalamsha some examples of *Ostrea cucullata* were discovered, and these we believe to have truly belonged to the lower beds of the terraces and not to have been derived from the undoubted marine Middle Pliocene beds of Sidmant. If the existence of *O. cucullata* in these terraces could be confirmed we should undoubtedly class them as marine and of Middle Pliocene age. But the single evidence of the Qalamsha shells is not sufficient, and confirmatory occurrences must be obtained and, if possible, the relation of the terraces to Schweinfurth's marine Sidmant beds determined, which has not been yet done.

M.—Gypseous deposits, probably dating from the close of the Pliocene Period.

Of distinctly later date than the gravel-terraces are the widely distributed gypseous deposits of the Fayûm and Nile Valley. These deposits are found covering the plain which separates the Nile Valley cultivation from the Fayûm depression, gradually rising from the level of the former until they overlie the gravels capping the summit overlooking the Fayûm (Section XXI).

Near the Pyramid of Medum the following beds are seen at the edge of the desert plain:—

Top.		Metres.
Pure, gravelly, or marly gypsum.		1–2
Clayey shales with gypsum and salt		1–1½
White marly limestone with much salt and fish-remains (fish-scales, etc.)	probable part of Ravine beds.	2
Yellow sandstone with fish-scales, etc.	probable part of Ravine beds.	3

The gravel deposits along the east side of the Fayûm are always capped by a gypseous bed. The latter is often 2 metres thick and frequently occurs as solid and almost pure white crystalline gypsum; sometimes it is calcareous and is frequently deposited in a tufa-

ceous manner, especially resembling a tufa on the weathered surface. At other times it passes into a yellowish compact mass and may be very saliferous.

Frequently the deposit is full of rounded pebbles, the latter being often in the greater proportion and forming a sort of gypsum-cemented conglomerate. Not unfrequently it is impossible to draw any divisional line between the terrace gravels and the gypseous gravels above. Probably they are both closely connected and of Upper Pliocene age.

N.—Summary of the Pliocene Period.

From the above descriptions it is probable that the Pliocene period is represented in the Fayûm by the following :—

(1) Marine beds of Sidmant, undoubtedly of Middle Pliocene age and reaching a level of from 60 to 70 metres above present sea-level.

(2) Borings on exposed rock-surfaces at two distinct levels, the lower 0-20 metres, the higher some 112 metres, above sea-level. These borings appear to be the work of marine boring mollusca, and although those on the lower level may perhaps be of Middle Pliocene age with the Sidmant beds, the similar examples discovered at a much higher altitude (112 metres), point to the sea having attained a much higher level in later, perhaps Upper Pliocene, times.

(3) An extensive beach or terrace of gravel on the south-east, east, and north sides of the Fayûm, attaining a maximum level of about 170 to 180 metres above sea-level.

All the known facts seem to be satisfied if we imagine that in the Middle Pliocene the sea occupied the area, depression probably continuing until the 112 metre level with the highest borings was reached. Perhaps the lowest part of the terraces was formed during this time. In the later Pliocene times we may infer that the area was occupied, up to 180 metres above present sea-level, by a vast inland lake, perhaps of brackish water, connected with the sea on the one hand and the fiord or lakes of the Nile Valley on the other, the deposits of which have been described elsewhere[1].

Along the margins of this gigantic lake, these great accumulations of gravel might well have been formed, chiefly of material derived from the immediate shores, augmented perhaps by a certain amount of sediment brought by river-currents from the south.

Finally, from the way in which the gypsum and gypseous deposits are laid on the terrace gravels, and from their extension and thickness, we may presume that they were deposited on the bottom of just such a lake on evaporation of its water, when the sulphate of lime in solution, becoming more and more concentrated, may have been finally precipitated.[2]

[1] BEADNELL, *Découvertes Géologiques Récentes dans la Vallée du Nil et le Désert Libyen,* VIII[e] Congrès Géol. Intern. 1900. Paris 1901, pp. 25-27.

[2] Doubt has recently been thrown by American writers on the possibility of large or thick deposits of gypsum being formed by precipitation. See R. S. SHERWIN. *Notes on the theories of origin of gypsum deposits,* Kansas Acad. Sci. Trans. Vol. 18. 1903, pp. 85-88.

SECTION XIII.—PLEISTOCENE.

The course of events in Pleistocene times is at present obscure. As far as can be judged it was during this period that a freshwater lake, the precursor of the great Mœris, came into existence. It might be thought that the early Pleistocene prehistoric lake was a relic of the still older body of water of Pliocene times, in which the gravel terraces and gypseous deposits were laid down. But such a remnant would have been of a high degree of salinity and could not have given rise to the fresh water Mœris. Most probably at the close of the Pliocene period, after the formation of the gypseous deposits, the area became elevated and cut off from the sea and from the Nile Valley marine fiord; probably an extensive body of water remained as an isolated lake, but this, cut off from external supply, would have gradually evaporated, its salt being left as a superficial deposit on the dried up bed. In early Pleistocene times we may presume the area became dry and was gradually eroded to its present shape and depth. The superficial deposits of salt and gypsum were for the most part removed as the depression was deepened, while the continuous terrace of gravel laid round the greater part of the rim was broken through, except where protected in favourable localities, the constituents being washed down and spread out over the lower ground. In course of time the region was moulded to its present form and dimensions, or rather to what it would be if the local alluvial deposits were stripped off and the water of the lake baled out. The area was an inland depression, probably sparsely vegetated like the rest of the higher country and separated from the Nile Valley by a low rocky ridge surmounted by a more of less continuous terrace of gravel of considerable height and thickness. In our opinion desert conditions had already set in before the early Nile broke down the ridge and formed a lake in the Fayûm ; the date when this important event first took place is a matter or considerable doubt, as has already been mentioned (pp. 24, 25). We know that at the close of the Pliocene period the Nile Valley was a marine fiord (connected with the Fayûm and the Mediterranean) which was replaced in Pleistocene times, probably in consequence of slight elevation, by a series of fresh water lakes throughout the valley. These lakes were probably two or three in number and drained one into the other ; the exact position of the barriers is as yet a matter of conjecture. Within these lakes thick lacustrine deposits were accumulated, so that the basins eventually became to a great extent silted up. In later Pleistocene times drainage down the Nile Valley appears to have become more pronounced, the barriers between the lakes were broken down and the river cut for itself a channel through the lacustrine beds, filling up the old lake basins. From this time onwards to early prehistoric times the bed of the river would appear to have steadily fallen, as it eroded its channel deeper and deeper. That this early Nile was a river of considerable size is evident from the amount of erosion it accomplished in the trough of the valley, whence the older lacustrine beds have been almost completely removed. Probably in the lower part of its course it swept against the base of the dividing ridge between the Nile Valley and the Fayûm depression. If, as we imagine, the river was at that time flowing some

20 metres higher than at present its currents would have met with little resistence from the loosely cemented terrace of gravel which formed the upper part of the dividing ridge. Once this was broken down the waters must have poured into the depression behind, until a lake of considerable size was formed. The sediment spread out over the floor in the shape of a fan, while at the same time deposits of sands and fine clays, blown and washed into the waters from the surrounding shores, were being slowly accumulated in the quieter and more remote parts of the lake.

For some time subsequent to the first connection between the Fayûm depression and the Nile, the latter continued to fall in level owing to continued erosion along its course, possibly the Fayûm again became completely isolated for a time. Subsequently in the earliest historic times under changed conditions the river commenced to carry and lay down the modern alluvial deposit of "Nile mud", and from this time to the present day its bed has gradually risen. This is shown by the high Nile flood-readings on the early gauges of the Nile Valley; the nilometer at Roda shows a difference of 1·22 metres in 1026 years, or an annual rise of 0·12 centimetre, which is equivalent to 12 metres in 10,000 years[1]. Whether there was ever complete disconnection between the Nile and the originally formed lake in Pleistocene times is uncertain, but even so it was probably only during a comparatively short period: in early historic times the rise of the Nile bed must have brought about a reconnection.

The geological evidence for the existence of a great freshwater lake in Pleistocene and prehistoric times is afforded by the well-marked lacustrine clays and sands which are found over such a large area of the northern and western deserts of the Fayûm; the great extent of this lake will be seen by an examination of the accompanying maps. Its area must have been about 2250 square kilometres or about ten times the size of the modern Birket el Qurûn. The western limit may even have been further west than shown on fig. 10.,[2] as some of the desert in the neighbourhood of Gar el Gehannem is very low-lying; or there may have existed subsidiary lakes in that direction. The upper limit of these ancient lacustrine clays is between 22 and 23 metres above sea-level, which exactly agrees with the figure adduced by Sir Hanbury Brown as the height of the more modern Lake Moeris from the evidence of levels. That Lake Moeris was simply the older prehistoric lake placed under artificial control admits of no doubt; the difficult question being as to when the lake first came into existence in prehistoric times.

The clays abound in freshwater shells and semi-fossil fish-bones of exactly the same species of fish (siluroid, etc) as still inhabit the Birket el Qurûn; probably some are even hardly different specifically from the Middle Eocene forms of the district. In addition remains of large animals are common, and include *Hippopotamus*, *Elephas*, *Bubalis*, sheep or goat, and *Canis*, with crocodiles and turtles, etc.[3]

[1] Egyptian Irrigation (1899), p. 32.

[2] The southern limits of the site (broken line) are taken from the maps of Brown and Willcocks.

[3] The mammalian remains collected from these lacustrine clays have not yet been systematically examined. Dr. Andrews has however determined some of the genera present; see, "*Notes on an Expedition to the Fayum, Egypt*", Geol. Mag. No. 470 Aug. 1903, pp. 337-343.

ISOLATED SAND-DUNE NEAR GAR EL GEHANNEM.

Martens [1] has described the following species of mollusca from Schweinfurth's collections :—

Unio abyssinicus. Mart.
U. Schweinfurthi, Mart.
Corbicula fluminalis, var. *consobrina* Caill.
Neritina nilotica, Reev.
Valvata nilotica, Jick.
Cleopatra pirothi, Jick.
C. pirothi, var., *unicarinata*, Mart.
Bithynia aff. *Boissieri*, Charp.
Melania tuberculata, Müll.
Limnaea natalensis, Krauss.
L. mœris, Mart.
L. palustris, Mull.
Planorbis subangulata, Phil.

Blanckenhorn has pointed out [2] that this fauna is of special interest and differs from all fossil and living faunas in Egypt. It might be compared with the *Melanopsis*-fauna of the Nile Valley if the exceptional *Limnaea* were replaced by *Melanopsis* or *Paludina*. Its *Unio Schweinfurthi* recalls the youngest alluvial deposits of the Nile Valley, 2nd Cataract, Kom Ombo and Silsila ; at these places, however, the beds containing the species in question are at least 20 metres above mean water level of the present day.

The sub-fossil fauna of the Fayûm alluvium, in addition to those forms everywhere met with in the Nile Valley, includes *Neritina nilotica* and *Melania tuberculata*, which are common forms of the *Melanopsis* stage, as well as *Unio abyssinicus* and *Valvata nilotica*. In common with the present fauna of the Birket el Qurûn it has the five forms belonging to the genera *Corbicula*, *Neritina*, *Valvata*, *Melania*, and *Planorbis*. The sub-fossil fauna, which passes into the modern fauna of the Birket el Qurûn, shows connection with the Mediterranean and Blue Nile, but has a total absence of White Nile forms such as *Ampullaria*, *Lanistes*, *Cleopatra bulimoides*, *Spatha* and *Aetheria*. Moreover *Limnæa palustris*, although identical with the form found on other Mediterranean coasts, is as yet entirely unknown from the Nile Valley. Blanckenhorn concludes that the diluvial subfossil deposits of the Fayûm were produced when the climate of Egypt was damper and more Europæan, the Nile carrying more arenaceous sediment in place of the mud of to-day and running at higher level, as it did when the shells of *Unio Schweinfurthi* were enclosed in the deposits of Jebel Silsila. Blanckenhorn thinks the Nile obtained access to the depression during the last European ice period. This last supposition, coupled with the above comparison of the Fayûm fresh-water fauna with the Melanopsis stage of the Nile Valley Pleistocene series, shows that in regarding the early Fayûm lake as dating from prehistoric times Blanckenhorn and the writer are in agreement.

Section XIV.—RECENT.

We may divide the Recent period into two epochs, Prehistoric and Historic, always remembering that the line of demarcation is not much more distinct than that between Recent and Pleistocene.

[1] Martens *Subfossile Süsswasser-Conchylien aus dem Fajum*, Sitz. Ber. Gesell. naturforsch. Freunde, Berlin July, 1879, S. 100 u. Oct. 1886, S. 126.
[2] *Geologie Ægyptens*, pp. 444-446.

O.—Prehistoric.

The abundance of worked flints on the desert just within and around the site occupied by the Fayûm lake in late Pleistocene and prehistoric times, shows that the shores were eventually inhabited by people who made and used these primitive tools. That the edge of the lake was abundantly wooded is shown by the thousands of well preserved tamarisk stumps met with at the present day in situ (Plate XIV) in the clays throughout the former margin of the lake.

The implements occur chiefly along the margin of the highest level of the old lake, and have probably in many cases been buried in the lake clays until the present time, which would account for their beautiful state of preservation. We have not, however, yet actually detected them enclosed within the clays, although commonly found lying on the clean wind-worn surface. From the fine degree of workmanship we may undoubtedly refer these flint implements to the Neolithic or later stone-age, although the exact date is doubtful. That they were made and used while the lake still stood at its highest level seems certain, but as we have shown above, the lake, as a sheet of water up to 23 metres above sea-level or thereabouts, probably existed far anterior to the Egyptian historic period. They might, on the other hand, as far as the evidence from the position of the lake goes, have been used by the inhabitants of the lake-margin down to the great reclamation which took place in Ptolemaic times. As it seems impossible to date them by comparison with flints of known age from any Egyptian period, we may perhaps conclude that they are at least of older date than the earliest Egyptian records.[1]

P.—Historic.

In historical times, under conditions almost identical with those of the Nile of to-day, there would have been an annual inflow during the flood and outflow back to the Nile when the latter subsided; during the inflow a constant supply of Nile mud was brought into the lake and deposited on the surface of the earlier alluvium, continually augmenting the thickness of the latter and raising its surface, until in the central area marshy land began to appear. In the XII Dynasty this natural backwater of the Nile, which acted as a more or less efficient regulator of high and low floods, was brought under human control by Amenemhat I, and a considerable area of land reclaimed from the shallowest part of the lake, or that part of the country now lying near Edwa, Medinet el Fayûm, etc. The new artificially controlled lake was called Moeris, and its wonders are mentioned by Herodotus, Diodorus Siculus, Strabo and Pliny.

The actual position of Lake Moeris has been the subject of much discussion, the late

[1] For figures and details of these flints see a paper by the writer, *Neolithic Flint Implements from the Northern Desert of the Fayûm, Egypt*, Geol. Mag., Dec. IV., Vol. X., pp. 53–59, Febr. 1903.

Linant de Bellefonds[1] having asserted that it was a high-level lake, quite distinct from the Birket el Qurûn, occupying the gap in the hills by which the Bahr Yusef enters the Fayûm, its encircling bank commencing at Edwa and passing through Biahmu, Medinet, etc. Sir Hanbury Brown has,[2] however, completely demolished Linant's theory, which is shown to be absolutely untenable; and has proved conclusively that the ancient Mœris occupied the greater part of what is now the cultivated land, as well as the area covered by the present lake and a considerable part of the surrounding desert, the reclaimed land being in fact part of the very district Linant supposed the lake to have occupied. Since the publication of Brown's work complete corroborative evidence has been forthcoming from two distinct sources, one archæological, the other geological. The latter has already been mentioned.

FIG. 10.—Sketch Map showing approximately the site of Lake Moeris.

It was clear from the map of Claudius Ptolemy that the route through the Fayûm to the Oasis Parva left Bacchias near the north end of the lake, and passing between Arsinœ and Lake Mœris, reached Dionysias near the other end. The archæological researches of Messrs. Grenfell and Hunt[3] have shown that Bacchias occupied the site of the modern Um

[1] *Mémoires sur les principaux travaux d'utilité publique exécutés en Egypte depuis la plus haute antiquité jusqu'à nos jours.* 1872-1873, Chap. II.

[2] Op. cit. pp. 28-40.

[3] "*The disposition of the Lake Mœris,*" in the Archæological Report of the Egypt Explor. Fund 1898-1899, Pt. I. D., pp. 13-15.

el Atl close to one end of the Birket el Qurûn, while Dionysias was probably in the neighbourhood of Qasr el Banat or Qasr el Qurûn. Thus the Ptolemaic Lake Mœris was almost identical with the modern Birket el Qurûn. Neither did the sites excavated yield a trace of anything older than the third century B. C. Theadelphia and Philoteris were founded in the reign of the second Ptolemy, when a great reclamation of the land from the lake took place, and probably Euhemeria, Dionysias, Karanis and Bacchias date from the same reign.

The archæological evidence is thus briefly summed up by Grenfell and Hunt: "Originally the lake filled the whole basin of the Fayûm, the first reclamation being carried out by Amenemhat I, who built the great dam at El Lahûn, where the Bahr Yusef enters the province, and recovered the high ground near the entrance as far as Biahmu, and a point between Abshawai and Agamiin. This remained the Pharaonic province until the time of Herodotus, when the water still came up to the colossi at Biahmu. Subsequently all the land now cultivated below the level of the Pharaonic province was reclaimed, chiefly in the reign of Ptolemy Philadelphus, when Lake Mœris was reduced nearly to the size of its modern representative, the Birket el Qurûn".

Present day Fauna of the Birket el Qurûn.

As mentioned above, the Pleistocene fauna of the Fayûm differs in one or two particulars from the fauna of the present day. The commonest living molluscan forms include the following:—

Corbicula fluminalis.
Neritina nilotica.
Cleopatra bulimoides.
Hydrobia stagnalis.
Valvata nilotica.
Melania tuberculata.
Planorbis Ehrenbergi.
P. marginatus var. *subangulata.*

Blanckenhorn[1] has pointed out that in this fauna *Hydrobia stagnalis*, as a typical brackish water form is of special interest. The species appears to have established itself in the Birket el Qurûn in modern times, as it has not been found in the youngest alluvium of the lake, nor is it known in the modern Nile fauna.

Modern Deposits: Blown Sand and Erosion.

Except for the gradual accumulation of silt over the bed of the Birket el Qurûn—sand and clay carried in by the wind and the fine sediment borne by the feeder canals—the only modern deposits of any importance are those of blown sand. The extensive arenaceous deposits of younger Tertiary age, forming the greater part of the continent from the latitude of the Fayûm to the Mediterranean shores, yield as a result of the action of denudation a constant and abundant supply of the raw material. The sand carried southwards by the prevailing winds accumulates as dunes in the lowest parts of the depressions, on the slopes of cliffs, and in all the less exposed localities. Wind swept areas remain free or are only gradually encroached on by slowly growing linear dunes originating in the wind-shadow of

[1] Blanckenhorn, op. cit. p. 463.

THE BIRKET EL QURUN NEAR THE WESTERN END.

some protecting hill or ridge. An unique example of such a dune is to be seen at the south end of the well-marked ridge a few kilometres east of Gar el Gehannem (Plate XV).

The main accumulations of blown sand are in the southern part of the Fayûm; large areas of the floors of Wadis Rayan and Moêla are covered with dunes, while in their immediate neighbourhood the material has accumulated to such an extent as to blot out entire cliffs and valleys; immediately to the west of Gharaq a considerable area is covered with small but steep dunes; and finally must be mentioned the great linear belt of sand, known as the Ghart el Khanashat, which starting from a point about midway between the Wadi Natrûn and Mogara comes to an abrupt termination some 24 kilometres before gaining the northern escarpment of the Fayûm depression (see page 23).

As might be expected in an area like the Fayûm, where sedimentary rocks of every type are met with, and where the wind never wants for a sufficient supply of the necessary sand, superficial erosion is everywhere well marked. We do not propose to study here the action of wind-borne sand and it will be sufficient to mention two localities where the effects are best seen; one is in the neighbourhood of Garat el Esh, where the most remarkable scoring and grooving is to be seen on the two beds of limestone capping the upper and lower cliffs of the Middle Eocene; the other is the Zeuglodon Valley, and here the sculpturing of the sandstone of the Birket el Qurûn series is of the finest and most unique description.

APPENDIX I.

PREVIOUS LITERATURE RELATING TO THE FAYUM.

ANDREWS C.W.—*Extinct Vertebrates from Egypt.* Parts I, II, Geol. Mag. N. S. Dec. IV. Vol. VIII, Sept. and Oct, 1901.

Notes on an Expedition to the Fayûm, Egypt, with description of some new Mammals, Geol. Mag. N.S. Dec. IV. Vol. X. Aug. 1903.

Further Notes on the Mammals of the Eocene of Egypt, (Pts I, II, III), Geol. Mag. N. S. Dec. V. Vol. I. March, April, May, 1904.

A note on the occurrence of a Ratite Bird in the Upper Eocene beds of the Fayûm, Egypt. Proc. Zool. Soc. London, 1904, Vol. I.

ANDREWS, C.W. AND BEADNELL, H.J.L.—*A preliminary note on Some New Mammals from the Upper Eocene of Egypt,* Survey Dept., P.W.M., Cairo, 1902.

A *preliminary Notice of a Land Tortoise from the Upper Eocene of the Fayûm, Egypt.* Survey Dept., P.W.M., Cairo, 1903.

BEADNELL, H.J.L.—*Découvertes Géologiques Récentes dans la Vallée du Nil et le Désert Libyen,* VIII. Congr. Géol. Intern. 1900. Paris, 1901.

The Fayûm Depression; a Preliminary Notice of the Geology of a district in Egypt containing a new Palaeogene Vertebrate Fauna. Geol. Mag. Dec. IV. Vol. VIII No. 450, Dec. 1901.

A preliminary note on Arsinoitherium Zitteli, Beadn., Survey Dept., P.W.M., Cairo, 1902.

Neolithic Flint Implements from the Northern Desert of the Fayûm, Egypt. Geol. Mag. Dec. IV. Vol. X. Febr. 1903.

BLANCKENHORN, M.—*Geologie Ægyptens* (Pts I-IV) Zeitsch. Deutsch. Geol. Gesell. Berlin, 1901.

Neue geologisch-stratigraphische Beobachtungen in Ægypten, S.-Ber. d. math.-phys. Classe d. Kgl. bayer. Ac. d. Wiss. Bd. XXXII, 1902, Heft III, München, 1902.

Die Geschichte des Nil-Stroms in der Tertiär-und Quartär periode, sowie des Palaeolithischen Menschen in Ægypten. Z. d. Ges. f. Erdk. Z. Berlin, 1902.

Nachträge zur Kenntniss des Palaeogens in Ægypten, Centralb. f. Mineral. No. 9. 1903.

BROWN, SIR HANBURY.— *The Fayûm and Lake Mœris,* London, 1892.

COSSMANN, M.—*Additions à la Faune Nummulitique d'Egypte,* Cairo, 1901.

DAMES, W.—*Uber eine Tertiäre Wirbelthier Fauna von der westlichen Insel des Birket-el-Qurûn in Fayûm (Ægypten).* Sitzungsber. Akad. Wissensch., Berlin, 1883.

DAMES, W. AND KAYSER.—*Uber Zeuglodonten aus Ægypten und die Beziehungen der Archæoceten zu den übrigen Cetacean.* Palaeont. Abhand. I.V. 5, Jena, 1894.

EDITOR GEOLOGICAL MAGAZINE.—*A New Egyptian Mammal (Arsinoitherium) from the Fayûm.* Geol. Mag. N.S., Dec. IV, Vol. X, Dec. 1903.

ELLIOT SMITH, G.—*The Brain of the Archaeocéti,* Proc. Roy. Soc. Vol. 71.

FLINDERS PETRIE.—*Hawara, Biahmu and Arsinœ,* Egypt. Explor. Fund Reports, 1889.

GARSTIN, SIR WILLIAM.—*Report upon the Basin of the Upper Nile,* Cairo, 1904.

GRENFELL AND HUNT.—*The disposition of the Lake Mœris,* Archaeol. Rep. Egypt. Exploration Fund. 1898-99. Pt. I. D.

LIERNUR, WESTERN AND SCOTT MONCRIEFF, SIR COLIN.—*Notes on the Wadi Rayan,* Cairo, 1888.

LINANT DE BELLEFONDS.—*Mémoires sur les travaux publics en Egypte*, Paris, 1873.

Mémoires sur les principaux travaux d'utilité publique exécutés en Egypte depuis la plus haute antiquité jusqu'à nos jours, 1872-1873.

LUCAS, A.—*A preliminary Investigation of the Soil and Water of the Fayûm Province*, Survey Dept., P.W.M., Cairo, 1902.

MARTENS. E.v.—*Subfossile Süsswasser-Conchylien aus dem Fajum.* Sitz. Ber. Gesell. naturf. Freunde, Berlin, 1879.

MAYER-EYMAR,—*L'oasis de Moëleh*, Bull. de l'Inst. Egypt., April, 1892.

Nouvelles Recherches sur le Ligurien et le Tongrien d'Egypte, Bull. de l'Instit. Egypt., April, 1894.

Die Versteinerungen der tertiären Schichten von der westlichen Insel im Birket-el-Qurûn See, Paleontogr. N.F.X., 3, (XXX).

OPPENHEIM, P.—*Zur Kenntnis alttertiärer Faunen in Aegypten*, (I). Palaeontographica, Dreif. Band. III, Public Works Ministry reports, 1889-1904. Abt. Erst. Lief. Stuttgart, 1903.

REINACH, V.—*Schildkrötenreste aus dem ägyptischen Tertiär.* Sonderabd. aus d. Abhand. d. Senckenb. natur. Gesellsch. XXIX, I. Frankfurt, 1903.

SCHWEINFURTH, G.—*Reise in das Depressionsgebiet im Umkreise des Fajûm*, Zeitschr. Ges. F. Erdkunde, Berlin, 1886.

A note on the Salt in the Wadi Rayan, Appendix II, Egyptian Irrigation (Willcocks), London, 1899.

SCOTT MONCRIEFF, SIR COLIN—*Note on the Wadi Raian Project*, Cairo, 1889.

STROMER, E.—*Zeuglodonten-Reste aus dem oberen Mitteleocän des Fayûm*, Bayer. Akad. Wissensch., Bd. XXXII, 1902.

Einiges über Bau und Stellung der Zeuglodonten, Zeitschr. d. Deutsch. Geolog. Gesellsch. 1903. See also Beiträge zur Paläont. u. Geol. Osterr.-Ungarins u. des Orients. Band XV. Heft II and III.

Afrika als Entstehungszentrum für Saugetiere, Zeitschr. d. Deutsch. Geolog. Gesellsch. 1903.

WHITEHOUSE, COPE.—*Bull. of the American Geographical Society*, 1882.

WILLCOCKS, SIR WILLIAM.—*Perennial Irrigation and Flood Protection in Egypt*, P.W.M. Report, Cairo, 1894.

Egyptian Irrigation, 2nd Edit. London, 1899.

The Assuan Reservoir and Lake Mœris, London, 1904.

ZITTEL, K. v.—*Geologie u. Palaeontologie der Libyschen Wüste*, Cassel, 1883.

APPENDIX II.

Paul Oppenheim has recently published[1] a description of a large collection of Egyptian lamellibranchs; the following is a list of the species of which examples have been collected in the Fayûm (including Rayan and Moêla). Figured species are marked by an asterisk.

*Gryphaea pharaonum, Oppenh.	Lower Mokattam.
*Ostrea (Gryphaea) Whitehousei, May.-Eym.	„
*O. „ Edmondstonei, May-Eym.	„
*O. „ histris, May.-Eym.	„
*Gryphaea (?) arabica, May.-Eym.	„
*O. elegans, Desh.	Upper (and intermediate) Mokattam.
*O. Fraasi, May.-Eym.	Lower and Upper Mokattam.
*O. Stanleyi, May.-Eym.	„ „
*O. Cailliaudi, May.-Eym.	Upper Mokattam.
*O. ramosa, May.-Eym.	Lower Mokattam.
*O. plicata, Sol.	Mokattam Series.
O. paucicostata, Oppenh.	Lower Mokattam.
O. Reili, Fraas.	Lower and Upper Mokattam.
O. Schweinfurthi, May.-Eym.	Upper Mokattam.
O. Sickenbergeri, May.-Eym.	„
*O. Hessi, May.-Eym.	Lower and Upper Mokattam.
*O. qeruniana, May.-Eym.	Mokattam Series.
O. gigantica, Sol.	Upper (and intermediate) Mokattam.
*O. (Alectryonia) Clot-Beyi, Bell.	Lower and Upper Mokattam.
*O. („) Bellardi, May.-Eym.	Lower Mokattam.
O. („) semipectinata, Schafh.	„
*O. („) Mehemeti, May.-Eym.	„
Carolia placunoides, Cantraine	Lower and Upper Mokattam.
*Pecten moëlehensis, May.-Eym.	Lower Mokattam.
*P. Cailliaudi, Oppenh.	Lower and Upper Mokattam.
Plicatula pyramidarum, Fraas	Upper Mokattam.
P. Bellardi, May.-Eym.	Mokattam Series.
P. indigena, May.-Eym.	„
*P. Schweinfurthi, Oppenh.	Lower Mokattam.
*Spondylus ægyptiacus, Newton	Mokattam Series.
*S. Rouaulti, d'Arch.	Lower and Upper Mokattam.
*S. perhorridus, Oppenh.	Lower Mokattam.
*Vulsella crispata, Fischer	Lower and Upper Mokattam.
*V. lignaria, Oppenh.	Lower Mokattam.
*V. moëlehensis, Oppenh.	„
*V. chamiformis, May.-Eym.	„
*Nacula Mœridis, Oppenh.	Upper Mokattam.
*Cucullaea dimehensis, Oppenh.	„

[1] *Zur Kenntnis alttertiärer Faunen in Ägypten.* Pt. I. *Der Bivalven, erster Teil.* Palaeontographica Bd. XXX, III.

*Arca subplanicostata, Oppenh.	Upper Mokattam.
*A. Tethyis, Oppenh..	Mokattam Series.
*A. uniformis, Oppenh.	Upper Mokattam.
*A. tenuifilosa, Cossm.	Mokattam Series.
*Pectunculus juxtadentatus, Cossm.	Upper Mokattam.
*P. aegyptiacus, Oppenh..	,,
*Cardita Viquesneli, d'Arch...	Lower and Upper Mokattam.
C. acuticostata, Lk..	,, ,,
*C. mokattamensis, Oppenh...	Upper Mokattam.
*C. fayumensis, Oppenh.	,,
*C. fidelis, May.-Eym.	,,
*C. Mosis, Oppenh...	Mokattam Series.
*Crassatella fajumensis, Oppenh.	Upper Mokattam.
C. Junkeri, May.-Eym..	,,
C. puellula, May.-Eym...	,,
*C. trigonata, Lk.	Mokattam Series.
*Lucina pharaonis, Bell...	Lower and Upper Mokattam.
*L. Rai, Oppenh.	Mokattam Series.
*L. polythele, Oppenh.	,,
*L. calliste, Oppenh..	,,
*L. gibbosula, Lk.	Upper Mokattam.
*L. fajumensis, Oppenh...	,,
*L. sinuosa, Bell.	,,
*Diplodonta cycloidea, Bell.	Mokattam Series.
*D. inflata, Bell..	,,
*Lucina (Diplodonta) corpusculum, Oppenh.	,,
*Cardium desertorum, Oppenh.	Upper Mokattam.
*C. Schweinfurthi, May.-Eym.	,,
*Cyrena (Corbicula) Blanckenhorni, Oppenh.	,,
*Cyprina aegyptiaca, Oppenh..	,,

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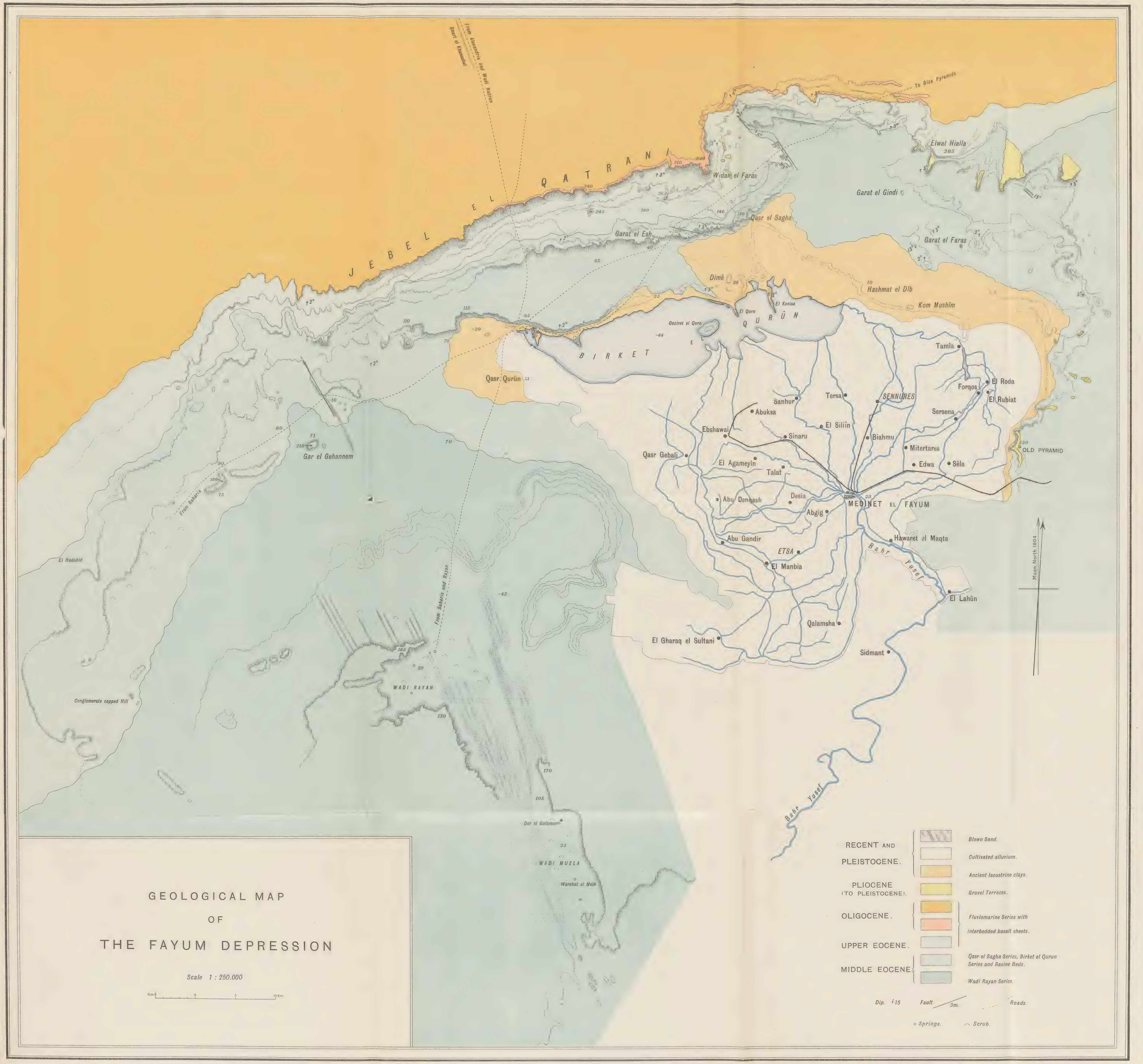
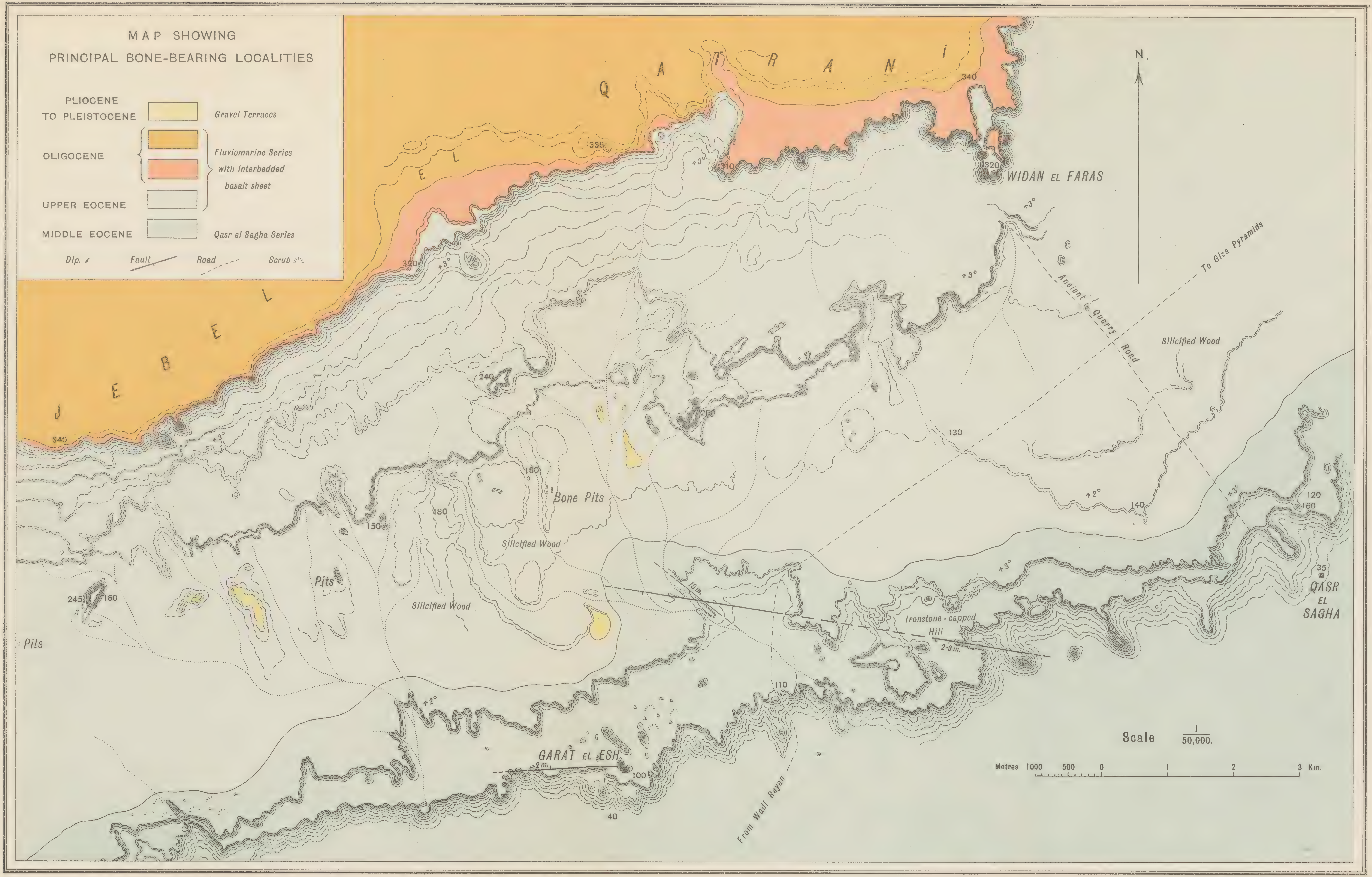

GEOLOGICAL MAP
OF
THE FAYUM DEPRESSION
Scale 1 : 250.000
JEBEL EL QATRANI
To Giza Pyramids
From Alexandria and Wadi Natrun
Elwat Hialla
Widan el Faras
Garat el Gindi
Qasr el Sagha
Garat el Esh
Garat el Faras
Dimê
Hashmat el Dib
Kom Mushim
El Qorn
El Kenisa
Geziret el Qorn
BIRKET EL QURÛN
Qasr Qurûn
Tamia
El Roda
Forqos
El Rubiat
Sersena
SENNURES
Tersa
Sanhur
Abuksa
El Siliin
Ebshawai
Sinaru
Biahmu
Mitertares
Edwa
Sêla
OLD PYRAMID
Qasr Gebali
El Agameyin
Talat
Abu Dengash
Desia
Abgig
MEDINET EL FAYUM
Hawaret el Maqta
Bahr Yusef
Abu Gandir
ETSA
El Manbia
El Lahûn
Qalamsha
El Gharaq el Sultani
Sidmant
Magn. North 1904
Gar el Gehannem
From Baharia
El Hadahid
From Baharia and Rayan
WADI RAYAN
Conglomerate capped Hill
Der el Galamun
WADI MUELA
Warshat el Meih
RECENT AND PLEISTOCENE.
Blown Sand.
Cultivated alluvium.
Ancient lacustrine clays.
PLIOCENE (TO PLEISTOCENE).
Gravel Terraces.
OLIGOCENE.
Fluviomarine Series with interbedded basalt sheets.
UPPER EOCENE.
MIDDLE EOCENE.
Qasr el Sagha Series, Birket el Qurun Series and Ravine Beds.
Wadi Rayan Series.
Dip.
Fault
Roads.
Springs.
Scrub.



Survey Dept. Cairo.

Plate XIX.

SECTION FROM THE BIRKET EL QURÛN THROUGH DIMÊ AND QASR EL SAGHA TO THE SUMMIT OF JEBEL EL QATRANI.

Horizontal Scale 1 : 50,000 1000 500 0 1 *kilometres*

Vertical Scale 1 : 12,500 0 125 250 500 *metres*

Recent and Pleistocene — Clays with pottery, freshwater shells, and fish remains, on plain between Qasr el Sagha and Dimê, and on slope from Dimê to the Birket el Qurûn.

Heights in metres approx: above Sea Level

Oligocene
1. Calcareous grit, sands and sandstones with silicified wood.
2. Basalt sheet, with occasional tuffs, etc: interbedded and contemporaneous.

Fluvio-marine Series (Upper part).

Upper Eocene (Passing up into Oligocene).
3. Calcareous grits and limestone bands with Melania, Potamides, Turritella &c. and clays, sands, and sandstones with Unio, Lanistes &c. Occasional vertebrate remains.
4. Variegated sands, sandstones and clays with impure limestones and calcareous grits.
5. Hard blue-grey compact cherty limestone with casts of Melania.
6. Variegated sands and sandstones with clays, and bands of calcareous grit and thin limestones.
7. Sands and sandstones with much silicified wood, overlain by clays, marls, calcareous grit and thin bands of limestone. Vertebrate remains include Arsinoitherium, Palæomastodon, Mœritherium, Megalohyrax, Saghatherium, Ancodus, Geniohyus, Phiomia, Pterodon, Eremopezus, with crocodilia and chelonia.

Fluvio-marine Series. (Lower part)

Middle Eocene — Upper Mokattam.
8. Hard yellow limestone capping interbedded sands and clays.
9. Alternating limestones, marls, clays, sands, and sandstones, frequently false-bedded. Vertebrates include Barytherium, Mœritherium, Eosiren, Zeuglodon, Gigantophis, Pterosphenus, Psephophorus, Thalassochelys, Podocnemis, Stereogenys, Tomistoma, and Propristis.

Qasr el Sagha Series

10. Limestones and calcareous sandstones often weathered into large concretionary blocks, frequently full of borings; interbedded sandy clays with Zeuglodon.
11. Sandstone, greyish limestone, overlying softer sandy clays and sandstones &c. more or less obscured.

Birket el Qurûn Series

12. Marls and marly limestones with gypseous clays; remains of Zeuglodon.

Ravine Beds

Plate XX.

SECTION FROM WADI RAYAN TO THE SUMMIT OF THE ESCARPMENT NORTH OF GAR EL GEHANNEM.

Horizontal Scale 1 : 200,000 0 2 4 6 8 10 *kilometres*

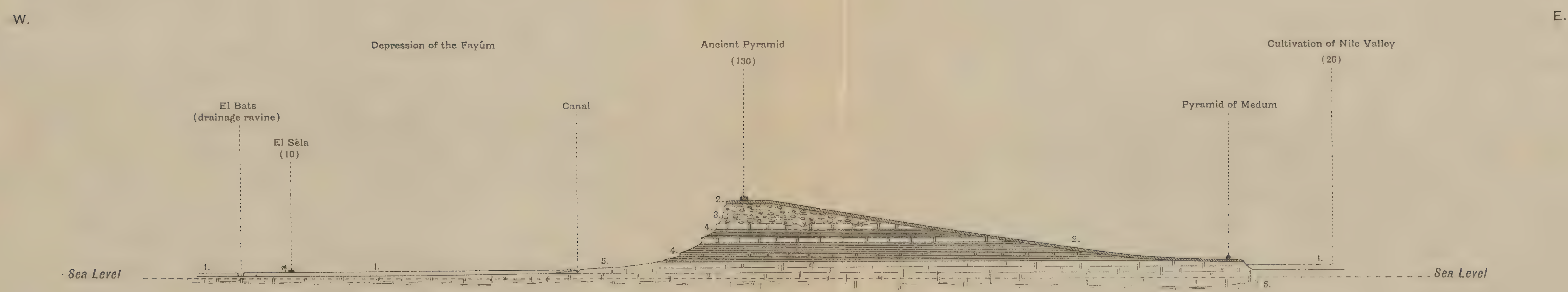
Vertical Scale 1 : 40,000 0 1000 *metres*

Heights in metres (approx.) above Sea Level.

UPPER EOCENE-OLIGOCENE	1.	Fluviomarine Series
	2.	Qasr el Sagha Series
	3.	Birket el Qurûn Series with Ravine Beds.
MIDDLE EOCENE	4.	Rayan Series

Plate XXI.

SECTION OF THE DESERT RIDGE SEPARATING THE NILE VALLEY AND THE FAYÛM.



Horizontal Scale 1 : 100,000 — 0 1 2 3 4 5 *kilometres*

Vertical Scale 1 : 10,000 — 0 100 200 300 400 *metres*

Heights in metres above Sea Level

RECENT.	1.	Alluvial loam, sands &c.
PLEISTOCENE-PLIOCENE.	2.	Gypsum and gypseous deposits
	3.	Terrace of gravel and conglomerate.
MIDDLE EOCENE. UPPER MOKATTAM	4.	Limestones, Marls, &c. (Birket el Qurûn Series).
	5.	Marly clays, and white marly limestones. (Ravine Beds).

SECTION FROM SIDMANT EL JEBEL IN THE NILE VALLEY THROUGH MEDINET EL FAYÛM TO THE SUMMIT OF JEBEL EL QATRANI, NEAR WIDAN EL FARAS.

Heights in metres approx. above Sea level.

RECENT-PLEISTOCENE
- a. Alluvial clays, sands, and loams of Nile Valley and Fayûm.
- b. Ancient clays of Lake Mœris.

PLIOCENE (OR PLEISTOCENE?)
- 1. Terrace gravel and conglomerate.

OLIGOCENE TO UPPER EOCENE — Fluvio-marine Series.
- 2. Sandstones with silicified wood, calcareous-grits, &c.
- 3. Basalt sheet, interbedded and contemporaneous.
- 4. Variegated sands, sandstones, clays and impure limestones, calcareous-grits, &c. with much silicified wood and vertebrate remains, especially near base.

MIDDLE EOCENE
- Qasr el Sagha Series — 5. Alternating limestones, marls, clays, sands and sandstones, with bone-beds.
- Birket el Qurûn Series — 6. Sandstones, sandy clays, sandy limestones and marls.
- Ravine Beds — 7. Marly clays, marls, and marly limestones.

MIDDLE EOCENE ESCARPMENT NEAR QASR EL SAGHA

1. Hard white limestone with numerous shell-casts and echinids (Echinolampas Crameri).
2. False-bedded sand and sand-rock with grey and green clays, and concretions and bands of ironstone. Ferruginous sandstone. Pterosphenus.
3. Hard calcareous and ferruginous clayey sandstone with brown ironstone concretions. Occasional fish-spines. Clays with massive veins of gypsum forming a stockwork.
4. Hard gypseous sandy limestone.
5. Sandy glauconitic clays with gypsum; oyster bed at base in places.
6. Friable limestone full of Carolia placunoides, Exogyra Fraasi, Ostrea Reili and Qerunia (Hydractinia) cornuta.
7. Purplish clays interbedded with ash-grey sands, with both ferruginous and highly carbonaceous bands with plant remains. Vertebrate remains include Moeritherium Lyonsi, Eosiren libyca, Zeuglodon Osiris. Psephophorus eocenus, Stereogenys Cromeri, Tomistoma africanum.
8. Hard grey concretionary sandstone. Sandy clays and sand-rock, occasional crocodile and fish remains.
9. Hard ripple-marked sandstones. False-bedded sandstones with clay partings; lignitic bands with lumps of pure charcoal occur.
10. Sandy limestone with Carolia, Turritella, etc.
11. Gypseous clays.
12. Limestone and calcareous sandstone with sharks teeth, Cardita fajumensis Trachelochetus bituberculatus. Turritella carinifera.
13. Slate blue and brown sandy gypseous clays with Moris nilotica, Exogyra Fraasi.
14. Sandstone and sand rock.
15. Friable limestone with Mesalia fasciata, M. oxycrepis, Turritella pharaonica, Alectryonia Clot Beyi. Ostrea Reili.

16, 17. Sands, sandy clays and clays with a double band of limestone; Astrohelia similis, Alectryonia Clot Beyi, Lucina fortisiana; numerous vertebrate remains including Mœritherium Lyonsi, M. gracile, Barytherium grave, Eosiren libyca. Zeuglodon Osiris, Gigantophis Garstini, Pterosphenus Schweinfurthi, Stereogenys Cromeri, Crocodilia and Siluroid remains.

18. Brown sandy limestone with Lanistes antiquus, Alectryonia Clot Beyi, Cardium Schweinfurthi, Exogyra Fraasi, Macrosolen Hollowaysi, etc. Clays.
19. Limestone with numerous Carolia placunoides and Turritella imbricataria.
20. Greyish-blue and brown ferruginous sandy clays and clays.
21. Friable shelly limestone with calcite veins.
22. Clays.
23. Hard yellow sandy limestone with Ostrea.
24. Clays with thin bands of fibrous gypsum.
25. Hard shelly limestone with numerous fossils including Turritella carinifera, T. imbricataria, Alectryonia Clot Beyi, Cardita fajumensis, Exogyra Fraasi, Euspatangus Cairensis, Qerunia (Hydractinia) cornuta.
26. Gypseous clays.
27. Friable limestone, gypseous, with Exogyra Fraasi, Alectryonia Clot Beyi, Carolia placunoides.
28. Sandy clays.
29. Friable sandy limestone with Carolia placunoides, Exogyra Fraasi.
30. Gypseous clays. Oyster limestone with Qerunia cornuta. Brown gypseous clays. Ferruginous sandstone bands. Sandy clays with gypseous partings.

Plate XXIV.

FROM GARAT EL ESH TO THE SUMMIT OF JEBEL EL QATRANI.

Horizontal Scale, 0 500 1000 Metres

Vertical Scale approximately three and a third times the horizontal.

Heights in Metres above Sea Level.

PLIOCENE (OR PLEISTOCENE?)....... a. Gravel Terrace.
UPPER EOCENE - OLIGOCENE........ b. Fluvio-marine Series
MIDDLE EOCENE....................... c. Qasr el Sagha Series

The numbered strata refer to the description of the section in the text.